ENCYCLOPÆDIA METROPOLITANA;

OR,

UNIVERSAL DICTIONARY OF KNOWLEDGE,

On an Original Plan:

COMPRISING THE TWOFOLD ADVANTAGE OF

A PHILOSOPHICAL AND AN ALPHABETICAL ARRANGEMENT,

WITH APPROPRIATE ENGRAVINGS.

EDITED BY

THE REV. EDWARD SMEDLEY, M.A.,
LATE FELLOW OF SIDNEY COLLEGE, CAMBRIDGE;

THE REV. HUGH JAMES ROSE, B.D.,
PRINCIPAL OF KING'S COLLEGE, LONDON;

AND

THE REV. HENRY JOHN ROSE, B.D.,
LATE FELLOW OF ST. JOHN'S COLLEGE, CAMBRIDGE.

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ENCYCLOPÆDIA METROPOLITANA;

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Second Division.

METEOROLOGY.

INTRODUCTORY OBSERVATIONS.

Introductory observations.

(1.) The condition of Man is so intimately connected with the various phenomena of the atmosphere, that he may, without impropriety, be regarded as a Meteorologist by nature. In all the varied circumstances of his state, whether as a wild and uncultivated savage, exposed to the fury and inclemency of the weather, or in the first stages of his civilization, when he has discovered some feeble means by which he can shelter himself from the descending torrent and the scorching energy of the sun; or when, as a shepherd and agriculturist, his interest leads him to watch with more anxiety the varying aspect of the sky, or as a mariner to connect the agitations of the ocean with the terrible force of the sweeping wind, he finds much of his happiness, and, at times, even his safety and existence, identified with the mighty and changeful character of the great fluid ocean, in which it has pleased the Almighty to place him.

Intimate connection of Meteorology with the condition of Man.

Difficult to trace the steps of its early History.

(2.) It would be difficult to trace the probable steps by which Man, during a long succession of Ages, has arrived at his present limited knowledge of atmospherical phenomena. The great causes which impeded the general march of Physical Science, necessarily exercised their influence on this branch as on others; and when we consider the peculiarly intricate conditions connected with every atmospherical problem; the large advances that must be made in many capital portions of knowledge, before one successful step can be made in this; the subtile nature of the medium which is the subject of investigation; its singular relations to moisture; the changes it undergoes with every alteration of temperature; in one region influenced by the full power of a vertical sun, and in another chilled by the frozen masses of the Polar zones; altering its circumstances on lofty hills, and again assuming new conditions in valleys; the islands of the West receiving the air that a few hours before lingered over the countries of the East; the warm breath of the South softening the rigours of the colder regions of the North; the vapour rising from the bosom of the Atlantic, dropping richness and fertility on the verdant shores of Britain; all these, and a thousand more complicated inquiries, beset the investigator at the very threshold of Meteorology, stimulating him to ardent investigation, and inspiring him with wholesome caution.

Causes which have retarded its advancement.

Connected with many of the most interesting branches of knowledge.

(3.) Meteorology, therefore, is not an insulated department of knowledge, detached from every other, but is intimately related to many of its most important branches. With Chemistry, for example, it stands connected in a highly interesting manner, and is blended with almost every page of its splendid History. The Chemical constitution of the atmosphere, must at all times have been an interesting object of research; and in later days, when this beautiful branch of inquiry has assumed so perfect a form, and unravelled so many of the hidden mysteries of Nature, its relations to Meteorology have been contemplated with redoubled interest. With the properties of Heat, and with the distribution of temperature over the varied and unequal surface of the globe, Meteorology necessarily holds an intimate connection. The principles are singularly curious which mark the gradations of climate, and disclose the interesting system of changes by which the atmospheric currents are produced; and a fertile and instructive branch of inquiry is opened by tracing, amidst the apparent uncertainty which characterises these diversified operations, something like the existence of laws; and by endeavouring to embody, in general analytical forms, representative values for them. It is thus that the Meteorologist has been enabled to obtain at the level of the sea, an approximative value of the temperature of his place of observation; and it is some evidence that a few successful steps, at least, have been made in the inquiry, when the mean temperature of a place can thus be obtained, sometimes within the fraction of a degree. Connected also with the same inquiry, is the consideration of the laws which mark the gradations of temperature, as we ascend above the Earth. There are approximative laws which the ingenuity of the

With Chemistry.

Heat.

Gradations of climate.

Gradations of temperature as we ascend above the Earth.

Plane of perpetual frost.

Vicissitudes of this great plane.

Scientific Meteorologist has reached, which connect the temperature of the loftier regions of the air with that of strata more accessible to Man; and in following up the gradual system of changes which mark the decrements of Heat, to the point at which water congeals, he has been enabled to fix in every latitude the limits of perpetual frost in the air; tracing it to its greatest point of elevation between the tropics, following it as it descends in the temperate regions, until it sinks to its lowest possible level in the frigid zones. In tracing also the varying altitudes of this magnificent plane during the uncertain vicissitudes of the seasons; marking its ascent during the tide of summer, and its descent when chilled by the blasts of winter; its Northern portion rising, when by the increments of the solar declination the temperature of Europe and Asia are augmented; or its Southern portion falling, as corresponding regions of the globe lose a part of the sun's vivifying power,—the subject has become connected with many other departments of the Natural Sciences, with the Geographical distribution of plants, for example, and has given to Meteorology another claim to high and attentive consideration.

Radiant Heat.

Solar radiation.

Terrestrial radiation.

(4.) With all the inquiries connected with radiant Heat, the subject of Meteorology is also most intimately connected. The atmosphere is influenced in different forms by the innumerable objects of the material world, each having a radiating power of its own, and all exercising an influence on the air. To trace in their fullest extent all the conditions connected with solar radiation, it became necessary for the Meteorologist to measure its effects in different latitudes; to follow its changing influence through the different months of the year; to estimate its progress during the several hours of the day; to trace its power on the varied tribes of vegetation; and to discover, under all its diversified circumstances, its maximum force. In like manner, in order to trace the laws which regulate terrestrial radiation, the Meteorologist has found the extent of its power in different latitudes; compared its influence upon plains and mountains, and measured its effects in the several months. All these inquiries have much extended the labours of the Meteorologist, and opened to him most fertile and instructive fields.

Density of the air.

Incessant fluctuations.

Applications of the Barometer to Physical Geography.

Refinements which have been introduced into Barometrical measurements.

Atmospheric tides.

Their remarkable uniformity in the torrid zone.

Discoverable also in the temperate zone.

(5.) While, by the agency of the Thermometer, these interesting phenomena have been disclosed, the Barometer has unfolded the most singular relations respecting the density of the air. The early cultivators of Meteorology must have almost despaired of being able to trace any thing like uniformity, amidst the incessant fluctuations which the Barometer displayed. Influenced, apparently, by a multitude of capricious causes, it must have seemed as if no clue existed by which any resemblance to a law could be detected; yet later observers, employing instruments of a more perfect construction, and extending their observations over a longer period of time, have arrived at many important conclusions of the greatest interest to Meteorology, and to the Physical Sciences in general. One of the most useful of these, is that equality of pressure which the mean altitude of the Barometer, at the level of the sea, has in every latitude disclosed, and which, as a standard in so many interesting Physical investigations, is of very great importance. In the applications of this instrument, also, to many important objects connected with Physical Geography; in making us better acquainted, for example, with the varied irregularities existing on the surface of the globe; determining the altitudes of the loftiest mountains, fixing the elevations of the sources of rivers, and of the positions of cities which the enterprise of Man has reared, in many situations far above the level of the sea; and making known, in all its minutest forms, the exact conditions of the terrestrial surface, an interest of the most important kind is given to this application of the resources of Meteorology. The refinements, also, which have been introduced into Barometrical measurements, by the employment of corrections; for the influence of capillary attraction, and the accession of the minutest atoms of moisture; the varied shapes which the ingenuity of the analyst has given to the formulæ of computation, all impart deep interest to this important branch of Meteorology. But it is from the delicate and uniform changes which the atmospheric tides display, that the Barometer becomes most important. In the torrid zone, these remarkable oscillations are disclosed with such admirable uniformity, that the Meteorologist contemplates the horary changes of the mercurial column, with a part of the certainty which marks the anticipations of the Astronomer. And even in the more varying regions of the temperate zone, where the changes from heat to cold are most capricious, and where the winds, ever changing, seem to impress the character of perpetual uncertainty on every thing connected with the Barometer, the Meteorologist has been enabled to detect an analogous system of changes.

Various relations of aqueous vapour to Meteorology

(6.) The state in which aqueous vapour exists in the atmosphere is also another important branch of Meteorology, and has been the object of much anxious inquiry. It is connected with all the interesting relations of the Hygrometer; with the series of laws regulating the force, the weight, and the expansion of vapour; the discovery of the term at which precipitation takes place from an alteration of temperature; the rate of evaporation under different temperatures and with different velocities of the wind; the consideration of the alteration of volume which air undergoes from Heat, and from the accession of vapour; its alterations of density, and the changes of its Specific Gravity in different states of saturation.

Dew.

(7.) The subject of dew likewise unfolds to the inquiring Meteorologist very interesting properties. No other investigation developes in a more perfect manner the singular relations of radiant Heat, and the laws by which caloric is communicated from one body to another. The vegetable world in particular opens a fertile and most interesting train of observation. Of the different grasses, each draws from the atmosphere during the night a supply of dew to recruit its energies, dependent on its form and its peculiar radiating power. Every flower has a force of radiation of its own, subject to changes during the day and the night; and the deposition of moisture on it is regulated by the peculiar law which this radiating power obeys; and this power will itself be influenced by the aspect which the flower presents to the sky, unfolding to the contemplative mind the most beautiful examples of creative wisdom.

Rain, hail, snow.

(8.) With the phenomena of rain, its primary formation, and the principles which regulate its descent; the formation of hail, the consideration of the laws that occasionally impart to it its beautiful crystalline forms; the still more delicate creation of snow, and the investigation of the endless groups to which particular conditions of temperature, and the peculiar circumstances attendant on the vapour actually existing in the air give birth, it is needless to say how closely Meteorology is connected.

Clouds, haloes, coronæ, &c.

(9.) The formation and classification of clouds, the varied and incessant changes which they present; the laws which regulate their suspension, and their gradual and sometimes sudden destruction by rain, belong all to this branch of Meteorological inquiry. So also the consideration of the laws which appear to influence the formation of haloes, coronæ, parhelia, &c. all of which owe their origin to the presence of aqueous particles existing in the air, place Meteorology in a most interesting relation to Light.

Electrical phenomena.

Aurora Borealis.

(10.) With all the phenomena of Electricity, the Meteorologist has claimed an intimate connection, ever since Franklin identified lightning with the ordinary electric fluid. The first conception of the thunder rod, was one replete with magnificence. To draw down silently from a cloud the matter, which, if discharged, would hurl destruction upon thousands, and destroy the finest monuments of Art, is an operation which seems to impart to the feeble hand of Man, a portion of the power of the Supreme. The beautiful phenomena of the Aurora Borealis, illuminating by their splendour those unexplored regions of Nature, which are covered at all times with a hoary desolation; their occasional descent into the temperate zones of the Earth; and the influence which their changeful coruscations is said to exercise in particular cases on the Magnetic needle, have identified in an especial manner the Science of Electricity with that of Meteorology.

Winds.

Sea and land breezes.

(11.) The general theory of winds, and their many modifications, opens also another interesting and instructive field of Meteorological inquiry. To trace the sources which produce those tremendous hurricanes and storms, that spread desolation over the fairest prospects of Nature, and which communicate likewise to the ocean its awful character and power; to consider the causes also of local winds; to account for the economy of Nature, in providing for the inhabitants of the tropical regions the refreshing interchanges of sea and land breezes; and for the existence of those periodical winds, which in some of the regions of the Earth perform, for definite periods, with the most exact uniformity, their stated and particular courses; facilitating the objects of navigation, and impressing a character of uniformity on the latitudes in which they abound; these, and many other inquiries of an analogous kind, awaken in an uncommon degree the attention of the Meteorologist.

Natural History. Indications of animals.

(12.) The cultivation of Meteorology is connected also, in an especial manner, with many of the departments of Natural History. With the habits of particular animals it is intimately identified, the sagacious observer being enabled to anticipate many atmospheric changes from an attentive observation of them. The common Swallow has always been considered as a weather-guide; and not only may the approach of rain be expected when she dips her wings in the stream, but even the gradations of climate may be marked by her approach. The voice of the solitary Crow, the clamours of the Pintado, and the activity of Ants, are all indications of coming rain; and by the mariner, the approach of the stormy Peterel, seeking for shelter under the wake of his vessel, is regarded as the harbinger of a storm. So that of the Fulmar to land, is a sign to the inhabitants of St. Kilda, that the West wind is very distant from them.

Meteorology useful in Practical Astronomy.

(13.) With the most exalted branch of Physical knowledge, Astronomy, the Science of Meteorology stands in many interesting relations. In determining the exact situation of a celestial object, the conditions of the internal and external temperatures require constant observation; nor must the movements of the Barometer be neglected, when the delicate problem of the Astronomical refractions is to be applied. Meteorology has indeed furnished to the latter many of its most important elements.

Figure and extent of the atmosphere.

(14.) In the inquiries also connected with the figure and extent of the atmosphere, the most beautiful applications of the law of gravitation have been made. The Mathematician, in considering the figures of the atmospheres of the Planets, is necessarily led, in a peculiar degree, to notice the volume of air surrounding the sphere which he inhabits. Its spheroidal form has called into action the most profound theories of analysis; and the Meteorologist rejoices to find, that the great laws which Newton delivered respecting the system of the World, meet with some of their most interesting applications in that atmosphere, whose incessant mutations it is his constant object to watch and record.

These different relations of Meteorology display the importance and value of the inquiry.

(15.) In this rapid sketch of the relations of Meteorology to some of the leading departments of Physical Science, an attractive picture is exhibited of the importance and value of the inquiry. The Meteorologist, while he is engaged, either for his amusement or instruction, in tracing some of the steps of the great system of atmospheric changes; in recording the incessant fluctuations of the Barometer, marking the vicissitudes of temperature, or estimating the force and influence of aqueous vapour, is thus preparing, sometimes unconsciously, materials for perfecting many of the other Sciences. While his primary object is, perhaps, to arrive at some of the elements connected with the great problem of climate, he is aiding the Astronomer in forming his catalogues of the stars. The inquiry therefore is not only valuable in itself, but is rendered doubly so by the relations which it bears to so many of the other Sciences.

Present condition of Meteorology

(16.) The condition of Meteorology at the present moment is one of very great interest. Much has been attained, and much, very much, remains to be done. The chief wants appear to be improvement in the instruments of observation, and *unity* amongst the observers. To copy the example of the most perfect of the Physical Sciences, Astronomy, it may be remarked, that that splendid department of knowledge has advanced to its present perfection, by the improvements that have been gradually imparted to its instruments of observation, and to the cautious and accurate deductions that have been drawn from their successful employment. In like manner must Meteorology advance, if similar methods be adopted. It is true that the elements connected with the inquiries of this Science are much more uncertain and variable; but *an extension of the field of observation*, both as regards *space* and *time*, must surmount many of them. The successive improvements of the Telescope have revealed to the Astronomer unnumbered clusters of stars; and the Micrometer, advancing from year to year in improvement, has enabled him to measure, with unhoped-for accuracy, the minutest intervals of space. So must an improved construction of the Barometer and other instruments employed in

Meteorological observations, guided by a more cautious spirit of induction, lead, in process of time, to like satisfactory results. When we reflect on the general condition of Physical Science, at the time when Bacon laid down the rules according to which Philosophical inquiries ought to be prosecuted, and contrast it with its condition now; how by the steady application of his inductive precepts many of its branches, which were characterised by uncertainty and doubt, have been reduced to comparative certainty and order; it is not too much to expect, that Meteorology, although still surrounded with so much difficulty and error, will hereafter attain its proper rank in the scale of the Sciences. The indefatigable recorder of atmospheric changes will then no longer be classed with the mere empiric. A survey of the past History of Physical knowledge will lead us to consider this conviction as neither romantic nor unnatural.

Sources of error which the Meteorologist has to avoid.

His objects.

General theories specious and seductive.

(17.) The great error which the cultivator of Meteorology has to avoid, is that tendency, which has more or less existed in different stages of its History, to a premature generalization departing from the narrow and cautious path which Bacon laid down. To accomplish an analysis of all the complicated phenomena of the atmosphere into simple and original principles, ought to be the aim and object of the Philosopher, and it is one well worthy of his lofty ambition and hope. But to proceed with success, "it is necessary to ascertain facts before we begin to reason, and to avoid generalizing in any instance, till we have completely secured the ground which we have gained. Such a caution, which is necessary in all the Sciences, is, in a more peculiar manner, necessary here, where the very facts from which all our inferences must be drawn, are to be ascertained only by the most patient attention."[*] There is something specious and seductive in all attempts at generalization; and it seems as if the mind, from the influence of improper habits, rather clung to the consideration of general principles, than to those severe and rigorous modes of observation, which the pure principles of the Inductive Logic require. But the History of knowledge is filled with the most melancholy proofs of the absolute futility of all attempts of the kind; and notwithstanding the splendour and success that have resulted from the application of the legitimate rules of Philosophy as laid down by Bacon, we yet find a strong tendency to violate them. It seems as if the mind delighted in hanging every thing on a single point, and adopting some principle as an infallible rule, to make the whole framework of Nature bend to its dictates. "It required nothing less," says an eminent Philosopher,[†] "than the united splendour of the discoveries brought to light by the new Chemical School, to tear the minds of men from the pursuit of a simple and primary element; a pursuit renewed in every Age with an indefatigable perseverance, and always renewed in vain;" and the History of Meteorology is filled with like impotent attempts. But checked as its growth has been by the application of mistaken rules, it must yet advance with success, if the principles of the Inductive Logic be rigorously applied to it. In all the other Sciences,[‡] the progress of discovery has been gradual, from the less general to the more general laws of Nature; and it would be singular, indeed, if, in so complicated an inquiry as Meteorology, one which labours under so many disadvantages peculiar to itself, a step should, all at once, be made to a single principle comprehending all the particular phenomena which we know. The Meteorologist must be content, like the cultivators of all the other departments of Natural Science, to advance by careful induction; to interrogate Nature under all her forms, and not to abandon the subject in despair, if her responses be not immediate.

Helps which Meteorology may derive from popular observations of phenomena.

Examples.

More general views of the Philosopher.

(18.) There is one peculiarity, however, belonging to the Science of Meteorology, which distinguishes it in a particular degree from all the other Sciences; and that is the helps it may receive from popular observations of phenomena. Saussure has remarked,[*] that "it is humiliating to those who have been much occupied in cultivating the Science of Meteorology, to see an agriculturist or a waterman, who has neither instruments nor theory, foretell the future changes of the weather many days before they happen, with a precision, which the Philosopher, aided by all the resources of Science, would be unable to attain." But there are no just grounds for the humiliation which the Swiss Philosopher has here alluded to; for "the knowledge of the Philosopher differs from that sagacity which directs uneducated men in the business of life, not in *kind*, but in *degree*, and in the manner in which it is acquired."[†] And when we consider, that the agriculturist and the waterman are always employed in the open air, with their minds constantly occupied with an object which interests them more *immediately* than it does the Philosopher, it can be no matter of surprise that they often group together facts, which, like the instinct of animals, serve to guide them in their predictions. The local sign which directs them may be a fog which rises at a particular hour, in some peculiar locality, the appearance of a cloud on the summit of a mountain, to which their attention has been directed by many early associations, or the song or migration of certain birds. But if these limited interpreters of Nature be transported to new seats, the symbols which guided them in their own locality will no longer be efficient; and other trains of observation must be begun, to fit them for their new condition. The views of the Philosopher are much more extended and general. His aim is not to limit his conclusions to a single locality, but to develop them under their most general form; and it is then that the superiority of well-directed observations becomes manifest. If, indeed, the Scientific Meteorologist could be constantly occupied like the agriculturist and the waterman, in watching the appearances of the heavens, our knowledge of atmospheric phenomena would soon be prodigiously increased; but unable thus to employ himself, it will be the object of the genuine cultivator of Meteorology to draw from the experience of even uneducated men all the helps he is able.

(19.) In the present rage for innovation, and for

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[*] Stewart's *Philosophy of the Mind*, vol. i. p. 400, 3d edition.

[†] De Gerando, *Hist. de Systémes*, tom. ii. p. 481, 482.

[‡] We have here applied to Meteorology what the eloquent Dugald Stewart has with so much truth said respecting the peculiar difficulties which beset the Philosophy of the Mind. Many of the reasonings of Stewart, such is their truth and generality, are as applicable to Physics as to Metaphysics.

[*] *Essais sur l'Hygrométrie*, ch. x.

[†] This beautiful and highly Philosophic maxim is taken from Stewart's *Outlines of Moral Philosophy*, p. 4, 4th edition, and is peculiarly applicable to the subject before us.

Evils to be anticipated from entirely rooting out all recollection of popular superstitions.

rooting up what are commonly called popular superstitions, much valuable information may be lost. Many of the common adages respecting the weather, have doubtless had their origin in the observance of Meteorological phenomena; and that Philosopher would but half perform his duty, who, dazzled by the splendid results which modern Science now discloses, should abandon without any examination the traditions that time has handed down. There are some phenomena of the atmosphere, which seem to have suggested to Man in different conditions of his state, ideas and forms of expression of the same common kind. In investigating these, under the dark and shadowy forms which the mutations of language have imparted to them, much important information may be disclosed; and connected as many of them are with cycles and periods of observation, they possess a very high value. Some attempt at a classification of the phenomena to which these traditions relate, would not be unproductive of advantage. Most of them have some foundation in Nature, and it is at least prudent for a Philosopher to keep them in view in the course of his inquiries.

(20.) It is thus by watching appearances, and diligently recording phenomena, generalizing observations, and disclosing in their fullest extent the grand system of signs by which Nature works, that Meteorology will advance to that perfection which its ardent cultivators desire.

Constitution of the atmosphere.

Constitution of the atmosphere.

(21.) The great volume of the atmosphere is composed of permanently elastic fluids, the whole of which are retained on the surface of the Earth by the law of gravitation. All eudiometrical processes, when skilfully performed, concur in proving that, apart from the carbonic acid and aqueous vapour which are present in atmospheric air, 100 volumes consist of 79 oxygen, and 21 nitrogen; or, including the two former ingredients, that it is constituted, at a mean temperature and pressure, of

Nitrogen gas....	77.5 by measure,	75.55 by weight.
Oxygen gas	21.0	23.32
Aqueous vapour.	1.42	1.03
Carbonic acid...	0.08	0.10
	100.00	100.00

(22.) It is the business of Chemistry to unfold the delicate processes by which these different relations are determined, and for these we refer the reader to our Essay on that Science; but we may notice here the remarkable fact, that with the exception of the aqueous vapour, the quantity of which varies with the temperature, as will be hereafter explained, the other ingredients of the atmosphere bear at all times, in every region of the globe, whether on the summits of the loftiest mountains, or at the lowest levels of the deepest valleys, the same relative proportion to each other. Thus, air from the Alps analyzed by the younger Saussure, from Spain by De Marti, from France and Egypt by Berthollet, from England and the Coast of Guinea by Davy, from the Peak of Teneriffe and from near the summit of the Andes by Humboldt, and from the still loftier elevation of 22,000 feet by Gay Lussac and Thenard, all gave results approaching as nearly as possible to each other.

This constitution the same in every region of the Earth.

(23.) It has been commonly supposed that the atmosphere must contain, diffused throughout it, minute portions of the vapours of all those substances with which it is in contact, even down to the earths and metals; and although the unknown ingredients which are occasionally mingled with the atmosphere, and which impart to it deleterious properties, are either of too subtile a nature, or present in too small a proportion, to be discovered by our imperfect instruments, yet Mr. Faraday has shown, in the *Philosophical Transactions for* 1826, that a *limit* exists to the production of vapour of any tension by bodies placed in vacuo, or in elastic media, beneath which limit they are perfectly fixed.

Mr. Faraday's discovery of a limit to vaporization.

Chemical constitution of the atmosphere.

(24.) Two views have been entertained of the nature of the union which exists among the several elastic fluids constituting the atmosphere. By the greater part of Chemists it has been considered as a Chemical compound, chiefly from the uniform nature of its composition, and from the fact that its several ingredients do not separate and arrange themselves according to their relative Specific Gravities. Mr. Dalton was the first who presented, under a distinct point of view, the remarkable theory, that of the various elastic fluids constituting the atmosphere, the particles of one have neither attractive nor repulsive power towards those of another, but that the weight or pressure, upon any one particle of any fluid mixture of this sort, arises solely from the particles of its own kind. According to this hypothesis, oxygen, azotic, and carbonic acid gases may exist together under any pressure, and at any temperature, while each of them occupies the whole space allotted for all. Each ingredient of the atmosphere, according to this view, exerts its own separate pressure in supporting the mercury of the Barometer, and performs, says Dr. Henry, the part assigned to it in the following table:

Mechanical constitution of the atmosphere.

	Inches of mercury.
The nitrogen gas exerts a pressure equivalent to	23.36
The oxygen gas	6.18
The aqueous vapour	0.44
The carbonic acid gas	0.02
	30.00

Latest views of Mr. Dalton respecting the constitution of the atmosphere.

(25.) In the *Philosophical Transactions for* 1826, Mr. Dalton has entered into an extended view of the principles by which he conceives the constitution of the atmosphere may be regulated; and to illustrate his views, he imagines two equal cylindrical tubes, A and B, to exist in contact with each other, perpendicular to the horizon, of indefinite lengths, closed at the bottom, but open at the top. Into the tube A he supposes an atmosphere of hydrogen to be introduced, equivalent to a mercurial column of 30 inches; and into the other tube B, an atmosphere of carbonic acid gas, capable also of supporting a column of 30 inches of quicksilver. Now supposing, he says, these atmospheres to remain, for an instant, of uniform density throughout the extent of each column, and that density to be the same as exists at the surface of the Earth, the altitude of the atmosphere of hydrogen would be about 66 miles, and that of the carbonic acid about 3.3 miles; these heights being to each other nearly in the ratio of 20 to 1. And if these atmospheres be afterwards expanded to their natural extent, equal elasticities of the two gases would be found to exist at altitudes, also in the ratio of 20 to 1; that is, if at two miles of elevation the atmosphere of carbonic acid supported 15 inches of mercury, that of hydrogen would support the same at 40 miles' elevation. Conceiving now these atmospheres to have acquired their perfect equilibrium, Mr. Dalton imagines numerous air-tight, horizontal partitions to be formed across the tubes, at equal intervals from the ground upwards; these intervals being either a foot or a mile, as may suit our purpose.

(26.) Supposing now a communication to be opened between each two horizontal portions of the tubes, an intermixture of the gases would follow, and finally such an equilibrium be obtained, that *one-half* of the gas existing at first in each division, would pass into the division opposite, and the other half remain in its original position. The whole weight of the gases in each entire tube would therefore be unchanged, and equivalent as before to 30 inches of mercury, half in each tube being carbonic acid, and half hydrogen gas.

(27.) In tracing the conditions of the gases as we ascend in the tubes, great differences would be found to exist, both as regards volume and weight. In the lowest division we should find equal volumes of carbonic acid and of hydrogen. At the height of two miles, one volume of the former gas would be found mixed with two of the latter; at four miles' elevation, the carbonic acid would be to the hydrogen nearly as one to four; and at 40 miles all the carbonic acid will have probably disappeared, but the hydrogen would remain of one-half its density in the primitive cell. Above the limits of the carbonic acid, wherever it may be, nothing but hydrogen gas would be found in each tube, up to the limits of the hydrogen atmosphere.

(28.) After a complete equilibrium has taken place between every two adjacent cells, Mr. Dalton conceives the horizontal divisions to be withdrawn. The descent of the upper part of the hydrogen column in each tube will be immediate, as there will be vacuities to be filled up in it. The same would take place in the column of carbonic acid, but the great body or weight of the mixed atmospheres would remain unchanged, excepting a slight condensation. The column of hydrogen in each tube would support 15 inches of mercury, and in all respects would resemble the upper half of the first column A, of hydrogen, that supported 30 inches, excepting a slight difference occasioned by distance from the earth and temperature; and the same may be said of the carbonic acid column in each tube.

(29.) But would this constitution of the mixture, Mr. Dalton asks, be permanent? Would a mixed atmosphere, which, in fact, as a whole, consisted of equal *weights* of carbonic acid and hydrogen, continue to exhibit, at the surface of the Earth, equal *volumes* only in mixture? Or, on the other hand, would not the whole be wrought up in due time into one uniform composition in all its extent, of twenty volumes of hydrogen with one of carbonic acid, as many suppose to be the nature of the Earth's atmosphere with regard to its component parts? To these questions, Mr. Dalton replies, by observing, that from what we know of the nature of mixed gases, each of the two gases would be disposed in the same manner as if the other was not present. They would be mixed in equal volumes at the Earth's surface; the carbonic acid would *rapidly* diminish in density as it ascends, terminating perhaps at 28 or 30 miles of elevation; and the hydrogen would *slowly* diminish in density, terminating perhaps at an altitude of eleven or twelve hundred miles.

(30.) In applying this doctrine to the Earth's atmosphere, supposing it to be in a quiescent state, Mr. Dalton neglects the carbonic acid and aqueous vapour, as inconsiderable in weight, and fixing the weight of the atmosphere at 30 inches of Mercury, he finds $\frac{21}{100}$ of $30 = 6.3$ inches, for the weight of the oxygenous atmosphere; and $\frac{79}{100}$ of $30 = 23.7$ inches, for the weight of the atmosphere of azote, since the weights of the respective atmospheres in this view are proportional to the *volumes* found at the surface of the Earth, and totally independent of their *Specific Gravities*. The weight of the aqueous vapour being variable, he fixes at 0.4 inches of mercury, and that of the carbonic acid at 0.03 inches.

(31.) This train of investigation has been conducted on the supposition of a *quiescent* atmosphere, or of one in a state of perfect equilibrium. How the case would be with regard to the Earth's atmosphere, such as it actually is, in a state of continual agitation, it is not easy to ascertain; and it is besides, says Mr. Dalton, rather a question to be decided by experiment and observation than by theory. Mr. Dalton, it appears, has a series of observations already made on this important subject; and he has promised to add them, as a supplement, to the paper from which these interesting extracts have been made.

Inquiries of Mr. Daniell.

Division into four parts.

(32.) The labours of Mr. Dalton, on the constitution of the atmosphere, have become the foundation of much of our knowledge in this important department of Science; and, accordingly, Mr. Daniell, the latest writer on the subject, has grounded his inquiries entirely on the principles established by the Manchester Philosopher. In his *Essays on the Constitution of the Atmosphere*, Mr. Daniell has divided his inquiries into four branches. In the first part, investigating *the habitudes of an atmosphere of perfectly dry, permanently elastic fluid, under particular conditions;* in the second, those *of an atmosphere of pure, aqueous vapour;* in the third, *the compound relations arising from a mixture of the two;* and in the fourth, *the application of such principles as the former sections of his inquiry may have disclosed, to some of the observed phenomena of the atmosphere of the earth.*

Investigation of the conditions of the first part, the temperature uniform.

(33.) In tracing the habitudes of an atmosphere of perfectly dry, permanently elastic fluid, surrounding a sphere in a state of rest, of uniform temperature in all its parts, and to the centre of which it gravitates equally, Mr. Daniell first shows that its height, density, and elasticity must be everywhere equal at equal elevations; and that the column of mercury which it would support in the Barometer, would be everywhere the same at the surface of the sphere. This is a necessary consequence of the law of Hydrostatics. The second condition is, that its density must decrease in a geometrical progression, in ascending through equal stages to its higher regions, because the density must be everywhere proportional to the superincumbent weight; and, thirdly, that its sensible heat must decrease progressively from below upwards.

The temperature to rise generally and equally in all its parts.

(34.) Mr. Daniell next supposes the temperature of the sphere to rise generally and equally in all its parts, and traces the consequent increase of elasticity, and total augmentation of height. There being no alteration in the ponderable matter of the vertical sections into which the atmosphere may be supposed to be divided, the total pressure will remain the same as before, and the Barometer at the base remain unaffected; but as a different distribution of the weight in the different horizontal sections must take place, the altitude of the mercurial column will be changed in every other situation.

Temperature to increase by equal increments from the Poles to the Equator.

(35.) Advancing a step higher in his inquiry, Mr. Daniell next imagines the temperature of the sphere round which the atmosphere is diffused, to increase by equal increments from the Poles to the Equator; and assuming zero for the temperature at the former, supposes that of the latter to be 80°. By limiting the pressure of the atmosphere to 30 inches of mercury at all parts of the surface of this sphere, the elasticity of the air must remain constant, but its Specific Gravity at the Poles will be much greater than at the Equator, and hence the atmospheric column in the Polar regions must be proportionally shorter than that in the Equatorial.

Polar and Equatorial currents.

(36.) The unequal densities of the aerial columns must produce a current from the Poles to the Equator; but as the difference of gravity becomes less as we ascend from the surface, and at a certain point is neutralized; so, on the other hand, the elasticity, which is constant at the surface, varies with the height; and the barometer stands higher, at equal elevations, in the equatorial than in the Polar column. This disproportion increasing with the elevation must, at some definite elevation, much more than compensate for the unequal density of the lower strata, and thus occasion a counter-flux from the Equator to the Poles.

(37.) These differences of gravity and elasticity may be regarded as distinct and opposite powers, their forces being measured upon the same scale. The excess of gravity may be estimated from the consideration, that the pressures of equal columns are as their Specific Gravities; and as, by Mr. Daniell's supposition, this excess of gravity is unopposed at the surface of the sphere by any excess of elasticity, so is it the exact measure of the force with which a Polar atmosphere would press upon an Equatorial, supposing the two in juxtaposition. The same excess of gravity is also the measure of the pressure which would be required at the Equator to equalize its density with that of the Poles. Could this increase of pressure actually take place, the aerial current would be reversed, and flow with the same force from the Equator to the Poles, the current being now occasioned by excess of elasticity, as it was before caused by excess of gravity.

Illustrative Table.

(38.) After assigning limits to the elevations of these currents, Mr. Daniell proceeds to estimate their velocities, and then furnishes, as in the following Table, the elasticity, Specific Gravity, and temperature of such an atmosphere, calculated upon his peculiar data, for every ten degrees of latitude, from the surface, by equal altitudes, to the height of 30,000 feet.

TABLE I.—*Numerical Values of the Elasticity, Specific Gravity, and Temperature, for every Ten Degrees of Latiude, of an Atmosphere of Dry Air surrounding a Sphere unequally heated from the Poles to the Equator, together with the Decrease of each, due to different Elevations.*

Height.	Poles.			Latitude 80.			Latitude 70.			Latitude 60.			Latitude 50.		
Feet.	Elast.	S. Grav.	Temp.	Elast.	S. Grav.	Temp.	Elast.	S. Grav.	Temp.	Elast.	S. Grav.	Temp.	Elast.	S. Grav.	Temp.
0	30.000	1.06666	0	30.000	1.06038	3.2	30.000	1.04685	9.6	30.000	1.02707	19.2	30.000	1.00000	32
5000	23.597	.86935	−18.5	23.652	.86542	−15.2	23.707	.85684	− 8.5	23.793	.84427	1.5	23.949	.82656	14.8
10000	18.587	.70856	−37.8	18.630	.70637	−34.3	18.724	.70140	−27.3	18.893	.69405	−16.9	19.106	.68321	− 3.1
15000	14.591	.57752	−58.8	14.642	.57654	−55.1	14.775	.57407	−47.7	14.962	.57061	−36.8	15.229	.56472	−22.4
20000	11.411	.47071	−82.1	11.484	.47057	−78.2	11.617	.46991	−70.2	11.827	.46904	−58.8	12.044	.46677	−43.6
25000	8.900	.38365	−109.1	8.965	.38408	−104.7	9.102	.38463	−96.3	9.314	.38558	−83.8	9.579	.38582	−67.5
30000	6.906	.31270	−140.3	6.978	.31352	−135.7	7.100	.31483	−126.5	7.302	.31699	−112.7	7.566	.31890	−95.1

Height.	Latitude 40.			Latitude 30.			Latitude 20.			Latitude 10.			Equator.		
Feet.	Elast.	S. Grav.	Temp.	Elast.	S. Grav.	Temp.	Elast.	S. Grav.	Temp.	Elast.	S. Grav.	Temp.	Elast.	S. Grav.	Temp.
0	30.000	.96668	48	30.000	.93960	60.8	30.000	.91978	70.4	30.000	.90625	76.8	30.000	.90000	80
5000	24.072	.80402	31.4	24.215	.78533	44.6	24.279	.77135	54.5	24.319	.76160	61.1	24.342	.75737	64.4
10000	19.338	.66878	14.1	19.531	.65639	27.9	19.675	.64693	38.1	19.738	.64017	44.9	19.779	.63735	48.4
15000	15.525	.55629	− 4.3	15.739	.54863	10.	15.898	.54258	20.7	16.012	.53806	27.7	16.060	.53640	31.4
20000	12.409	.46273	−24.5	12.673	.45856	− 9.4	12.811	.45507	1.7	12.974	.45220	9.3	13.043	.45150	12.8
25000	9.915	.38489	−47	10.162	.38327	−31.2	10.342	.38166	−19.4	10.467	.38010	−11.6	10.521	.37980	− 7.6
30000	7.852	.32016	−75.3	8.135	.32035	−55.9	8.313	.32010	−43.2	8.424	.31948	−35.	8.483	.31980	−30.7

(39.) The force of the Polar and Equatorial currents, as estimated on the same hypothesis, is given in the next Table.

TABLE II.—*Showing the Force of the Currents for different Heights at every Ten Degrees of Latitude.*

Height.	Latitudes 90 & 80.			Latitudes 80 & 70.			Latitudes 70 & 60.			Latitudes 60 & 50.			Latitudes 50 & 40.		
Feet.	Elast.	S. Grav.	Bal.	Elast.	S. Grav.	Bal.	Elast.	S. Grav.	Bal.	Elast.	S. Grav.	Bal.	Elast.	S. Grav.	Bal.
0	—	+.178	+.178	—	+.387	+.387	—	+.575	+.575	—	+.810	+.810	—	+1.034	+1.034
5000	−.055	+.112	+.057	−.055	+.246	+.191	−.086	+.367	+.281	−.156	+.531	+.375	−.123	+.693	+.570
10000	−.043	+.062	+.019	−.094	+.142	+.048	−.169	+.214	+.045	−.213	+.325	+.112	−.232	+.449	+.217
15000	−.051	+.028	−.023	−.133	+.070	−.063	−.194	+.101	−.093	−.260	+.176	−.084	−.296	+.261	−.035
20000	−.073	+.004	−.069	−.133	+.021	−.112	−.210	+.025	−.185	−.217	+.068	−.149	−.365	+.126	−.239
25000	−.065	−.013	−.078	−.137	−.015	−.152	−.212	−.028	−.240	−.265	−.007	−.272	−.336	+.029	−.307
30000	−.072	−.023	−.095	−.122	−.039	−.161	−.202	−.062	−.264	−.264	−.057	−.321	−.286	−.036	−.322

Height.	Latitudes 40 & 30.			Latitudes 30 & 20.			Latitudes 20 & 10.			Latitudes 10 & 0.			
Feet.	Elast.	S. Grav.	Bal.	Elast.	S. Grav.	Bal.	Elast.	S. Grav.	Bal.	Elast.	S. Grav.	Bal.	
0	—	+.854	+.854	—	+.648	+.648	—	+.447	+.447	—	+.208	+.208	Lower Polar Current.
5000	−.143	+.597	+.454	−.064	+.456	+.392	−.040	+.322	+.282	−.023	+.141	+.118	
10000	−.193	+.408	+.215	−.144	+.309	+.165	−.063	+.222	+.159	−.041	+.094	+.053	
15000	−.214	+.245	+.031	−.159	+.197	+.038	−.114	+.150	+.036	−.048	+.056	+.008	
20000	−.264	+.133	−.131	−.138	+.114	−.024	−.163	+.095	−.068	−.069	+.024	−.045	Upper Equatorial Current.
25000	−.247	+.051	−.196	−.180	+.052	−.128	−.125	+.051	−.074	−.064	+.010	−.054	
30000	−.283	−.008	−.291	−.178	+.008	−.170	−.111	+.021	−.090	−.059	−.011	−.070	

Remarks on the preceding Tables.

(40.) It may be remarked, with reference to these Tables, that a change of temperature, which equally pervades a column of air throughout its whole length, may effect an adjustment of density without disturbing the equiponderant mercurial column situated at its base; but the force of the compensating currents will be altered, and, under some circumstances, their courses even changed. An alteration of temperature, for example, in latitude 50°, will increase the force of the current from latitude 60° to 50° in its original direction, while that from 50° to 40° will be reversed: the wind, which had blown on the surface between the former parallels with a force of 0.810 inches, being increased to 2.560 inches; and that which moved between the latter parallels with a force of 1.034 inches, blowing now in the opposite directions with a force of 0.840 inches. Corresponding changes of velocity and direction ensue in the upper currents, and thus the compensation of pressure takes place.

(41.) Any cause also which tends to diminish gradually the Specific Gravity of a permanently elastic fluid column at its base, or, on the contrary, to augment its temperature at its superior limit, will affect it through its entire length; so that, if its heat be slowly increased below, its temperature must rise from one extremity to the other, and *vice versâ*. But although such a change may take place, without increasing the length of the mercurial column at its lower extremity, at all higher stations the Barometer will rise.

Effects of an increase of temperature of the upper strata of the atmosphere.

(42.) Let us next follow Mr. Daniell, when he imagines heat to be communicated to the upper strata of his atmosphere, and which, from some temporary cause, does not originate in, or extend to the lower. For this purpose, he supposes some increase of temperature at a definite altitude. The influence of the heat communicated will be felt in the superior strata, but those in the lower regions must, by the supposition, remain unchanged. The first effect which results will be an augmentation of elasticity in the upper beds of the atmosphere, which, exerting its force upon the high Equatorial current, will accelerate its velocity on one side, and diminish it on the other. The expanding air, not being laterally confined by a proportionate expansion of the neighbouring sections, will not accumulate above, but, flowing off, will cease its vertical pressure upon that column. The upper regions, therefore, will be rarefied, and become lighter, and pressing with less weight upon the lower, the Barometer will fall at the surface of the sphere, in proportion to the degree of expansion. The density of an elastic fluid being the result of its gravity acting upon its elasticity, by the reaction of these powers, any change in the vertical column must be communicated instantaneously throughout its entire length, and no inequality of density can for a moment exist.

Local accession of heat, commencing at a definite point, and gradually extending in depth.

(43.) To generalize still further, let us again imagine with Mr. Daniell, the local accession of heat, instead of pervading at once the whole of either horizontal section, to commence at some definite point, and gradually extend itself in depth. The disturbing cause will then affect the lower current, and the expanding volumes of air, not being checked by a simultaneous increase of elasticity in the adjoining columns, will rush forward with accelerated velocity, and the diminution of density occasioned by the excessive drain will be distributed throughout the column by mechanical adjustment. The fall of the Barometer would be proportionate to the extent to which the rise of temperature would reach in this progressive manner. A small increase, thus operating, will produce the same amount of depression, as if a greater expansion had been exerted in a more limited space.

(44.) In the following Table, the effect upon the Barometer is exhibited of a small partial increase of temperature, gradually extending itself throughout the aerial column, in conformity to the preceding changes.

Illustrative Table.

Table III.—*Showing the Effect upon the Barometer of a small partial Increase of Temperature, gradually extending itself throughout the Column.*

	Latitude 30, 1st Change.			Latitude 30, 2d Change.			Latitude 30, 3d Change.			Latitude 30, 4th Change.			Latitude 30, 5th Change.		
Height.	Elast.	S. Grav.	Temp.	Elast.	S. Grav.	Temp.	Elast.	S. Grav.	Temp.	Elast.	S. Grav.	Temp.	Elast.	S. Grav.	Temp.
0	*29.87	.9355	60.8	*29.74	.9314	60.8	*29.61	.9273	60.8	*29.49	.9232	60.8	*29.37	.9192	60.8
5000	24.21	.7819	* 46.6	*24.11	.7785	* 46.6	*24.01	.7751	* 46.6	*23.91	.7717	* 46.6	*23.81	.7683	* 46.6
10000	*19.45	.6546	27.9	19.45	.6518	* 29.9	*19.37	.6490	* 29.9	*19.29	.6462	* 29.9	*19.21	.6434	* 29.9
15000	*15.68	.5463	10.	*15.62	.5440	10.	15.62	.5417	* 12.	*15.56	.5394	* 12.	*15.50	.5371	* 12.
20000	*12.62	.4565	− 9.4	*12.57	.4545	− 9.4	*12.52	.4525	− 9.4	12.52	.4505	*− 7.4	*12.47	.4485	*− 7.4
25000	*10.12	.3816	−31.2	*10.08	.3800	−31.2	*10.05	.3784	−31.2	*10.01	.3768	−31.2	10.01	.3752	*−29.2
30000	* 8.10	.3190	−55.9	* 8.07	.3177	−55.9	* 8.04	.3164	−−55.9	8.01	.3151	−55.9	* 7.98	.3138	55.9

Table illustrative of the force and direction of the currents.

(45.) In the next Table, the effect of the preceding changes upon the force and direction of the currents is shown.

Table IV.—*Showing the Effect of the preceding Changes upon the Force and Direction of the Currents.*

	First Modification.						Second Modification.						Third Modification.					
	Latitudes 40 & 30.			Latitudes 20 & 30.			Latitudes 40 & 30.			Latitudes 20 & 30.			Latitudes 40 & 30.			Latitudes 20 & 30.		
Height.	Elast.	S. Grav.	Bal.	Elast.	S. Grav.	Bal.	Elast.	S. Grav.	Bal.	Elast.	S. Grav.	Bal.	Elast.	S. Grav.	Bal.	Elast.	S. Grav.	Bal.
0	+.63	+1.44	+2.07	+0.63	0.	+0.63	+.63	+1.44	+2.07	+.63	0.	+0.63	+.63	+1.44	+2.07	+.63	0.	+0.63
5000	+.37	+1.09	+1.46	+0.58	+0.08	+0.66	+.12	+1.09	+1.21	+.73	+0.08	+0.81	+.26	+1.09	+1.35	+.47	+0.08	+0.55
10000	+.21	+0.81	+1.02	+0.55	+0.140	+0.69	+.0	+0.81	+0.81	+.35	+0.14	+0.49	+.12	+0.81	+0.93	+.46	+0.14	+0.60
15000	−.21	+0.60	+0.39	+0.16	+0.18	+0.34	+.11	+0.60	+0.71	+.48	+0.18	+0.66	+.02	+0.60	+0.62	+.39	+0.18	+0.57
20000	−.26	+0.43	+0.17	+0.14	+0.20	+0.34	+.0	+0.43	+0.43	+.41	+0.20	+0.61	−.06	+0.43	+0.37	+.34	+0.20	+0.54
25000	−.25	+0.30	+0.05	+0.18	+0.21	+0.39	−.03	+0.30	+0.27	+.40	+0.21	+0.61	−.10	+0.30	+0.20	+.33	+0.21	+0.54
30000	−.28	+0.21	−0.07	+0 18	+0.22	+0.39	−.11	+0.21	+0.10	+.35	+0.22	+0.57	−.13	+0.21	+0.08	+.33	+0.22	+0.55

From latitude 40 to 30, it will be observed, that the force of the Polar current is greatly increased; while from 30 to 20, the effect is entirely reversed.

Remarks.

(46.) It may readily be imagined, continues Mr. Daniell, that irregularities thus introduced into these compensating movements, the consequence of diminished mechanical pressure, must of themselves be liable to produce changes of temperature in the atmospheric columns, foreign to the natural gradation; and that, amongst others, the atmosphere, in its upper parts, may be liable to greater depressions of heat than would result from the elevation alone. A gradual process of cooling taking place in the higher portions of a body of air, would communicate itself to the whole mass, in an analogous manner to the equal diffusion which would ensue from the slow communication of heat to the lower parts; that is to say, without producing any effect upon the Barometer at the surface of the sphere, or any irregularity in the gradation of temperature. But where the change is effected suddenly, by the admixture of a large body of cold air, a mechanical effect is produced by the increased pressure of the mass; and the equilibrium of density takes place before the adjustment of temperature. An atmosphere hence results, the heat of which decreases in a greater proportion than is due to the decrease of density; and the effect is analogous to that which arises from an irregular increase; and the Barometer must also rise to equalize the specific gravity.

(47.) It is not required here that we should point out all the means by which such changes of heat as we have alluded to may be effected, or that we should trace further the endless modifications of densities and currents which would result from their different applications. It is sufficient, says Mr. Daniell, at present, to have shown that, supposing them to arise, certain general consequences must follow.

Effects of the preceding changes upon the adjacent columns of the atmosphere.

(48.) In the preceding review of the labours of Mr. Daniell, we have found that he has contemplated the various changes that have been alluded to, with reference to the particular column of the atmosphere in which they had their origin. We shall now make our readers acquainted with his estimate of their effects upon those with which they are connected. For this purpose, we must remember, that it has been established as a principle, that the equal height of the Barometer, in every situation upon the surface of the sphere, was dependant upon the maintenance of the Equatorial and Polar currents, with a certain determinate velocity in the different parts of their courses; and that no disproportionate alteration or interruption in these could take place, without a corresponding effect upon the mercurial column. Now, upon a reference to Tables I. and II., continues Mr. Daniell, it will be found, that to keep the Barometer at 30 inches, under the parallel of 40, a current is required of the force of 0.854 inches towards the parallel of 30, counterbalanced by one in the contrary direction, of the force of 0.291 inches at the elevation of 30,000 feet; but by the unequal alteration of temperature, arising from the gradual extension of heat from one stratum of the atmosphere to another, the current at the surface will be increased to 2.07 inches, and continue with decreasing force to the height of 30,000 feet in the same direction. It is clear, therefore, that a much greater drain takes place upon this latitude, without an adequate compensating supply; and the Barometer must fall throughout the column. The atmosphere incumbent upon the parallel of 20 will be similarly affected by the same change of temperature at latitude 30. In its original state, the lower Polar current flows upon the surface with a force of 0.648 inches, and feeds this column with a supply of air. It is balanced at the height of 30,000 feet by an Equatorial current of 0.170 inches. The course of the former is now reversed, and the drain is increased in the contrary direction. A rapid fall of the Barometer must therefore ensue.

(49.) On the other hand, an increased afflux of air, beyond the usual supply, to any portion of the atmosphere, occasioned by the expansion of any of the neighbouring parts, must cause an increase of density; and the equiponderant column will of course be lengthened. It is easy to perceive, that these secondary effects must widely extend the influence of the original disturbing cause; and it is obvious, that every depression of the Barometer must be accompanied by an equivalent rise in distant parts of the elastic medium, and *vice versâ*. The local impulse, continues Mr. Daniell, extends its influence in this, as in all other fluids, by the laws of undulation. The mean pressure, at any moment of time, of all the waves upon the surface of the sphere, will be the pressure of the atmosphere at rest, and the average of a large number of oscillations at any particular spot, will approximate to the same quantity.

Effects of analogous changes in a longitudinal direction.

(50.) In the preceding inquiries we have considered the atmospheric changes to operate alone in a direction from the Equator to the Poles, or from the Poles to the Equator, as if the changes of temperature had operated entirely in parallels of latitude round the sphere. But Mr. Daniell enters also into the changes produced in a longitudinal direction from the operation of similar causes.

(51.) The atmospherical arrangements represented in Tables I. and II. resulted from the temperature of the sphere itself; but let us suppose the change referred to immediately following the last-quoted Table, to extend its influence to 10 degrees of longitude as well as to 10 degrees of latitude; is it not apparent that currents will be established at right angles to the directions of the former winds, and that they will tend to compensate the irregularity which has been introduced? The following Tables present the results of the calculation of these easterly and westerly currents.

Illustrative Tables.

TABLE V.—*Showing the Effects upon the Atmospheric Columns of a general Alteration of Temperature in the direction of the Longitude.*

Height.	Longitude 20 and 360.			Longitude 10.		
	Elast.	S. Grav.	Temp.	Elast.	S. Grav.	Temp.
0	30.000	1.00000	32.	30.000	.92960	60.8
5000	23.949	.82656	14.8	24.215	.78533	44.6
10000	19.106	.68321	−3.1	19.531	.65639	27.9
15000	15.229	.56472	−22.4	15.739	.54863	10.
20000	12.044	.46677	−43.6	12.673	.45856	−9.4
25000	9.579	.38582	−67.5	10.162	.38327	−31.2
30000	7.566	.31890	−95.1	8.135	.32035	−55.9

TABLE VI.—*Showing the Force of the Currents occasioned by the preceding Alterations.*

Height.	Longitudes 360 or 20 and 10.		
	Elasticity.	Sp. Gravity.	Balance.
0	0	+1.929	+1.929
5000	−.266	+1.301	+1.035
10000	−.425	+0.837	+0.412
15000	−.510	+0.496	−0.014
20000	−.629	+0.251	−0.378
25000	−.583	+0.076	−0.507
30000	−.569	−0.043	−0.612

Intermediate currents produced by the Polar and Equatorial currents.

(52.) The preceding forces operating, one in the direction of the meridian, and the other at right angles to it, must necessarily produce a system of intermediate currents, which will reach their destination with a Northern or Southern deflection.

Effects of an increase of temperature along an entire meridian.

(53.) There is, however, another of Mr. Daniell's views on this interesting subject, which we must not omit to notice; and that is, the increase of ten degrees of temperature which he supposes to take place along the entire range of a given meridian, and a diminution of heat of equal amount at the opposite point, all the meridians on each side being similarly affected in some ratio between the two. Mr. Daniell has computed the distribution of heat upon these two meridians, and also the two intermediate, for every ten degrees of latitude, the results of which are to be found in the next Table.

Illustrative Table.

TABLE VII.—*Showing the Distribution of Heat all over the Sphere, upon the supposition of a gradual Increase of Heat between the opposite Meridians.*

	Longitude 270	Longitude 0	Longitude 90	Longitude 180
Lat. 90	0	10.	0	−10.
Lat. 80	3.2	13.2	3.2	− 6.8
Lat. 70	9.6	19.6	9.6	− 0.4
Lat. 60	19.2	29.2	19.2	+ 9.2
Lat. 50	32.	42.	32.	22.
Lat. 40	48.	58.	48.	38.
Lat. 30	60.8	70.8	60.8	50.8
Lat. 20	70.4	80.4	70.4	60.4
Lat. 10	76.8	86.8	76.8	66.8
Lat. 0	80.	90.	80.	70.

Limit to the preceding increase of heat.

(54.) This increase of heat Mr. Daniell limits to the condition, that it takes place in so gradual a manner, as not to affect the Barometer at the bases of the different atmospheric columns. There will then be two currents established upon the surface of the sphere, in opposite directions on either side of the cold meridian towards the hotter, with a force of 1.304 inches; or rather, the body of air, which was before in motion from North to South, will now be deflected with this force to the East and West; and the whole lower atmosphere, excepting upon these lines where the effect would be null, will move from the Poles to the Equator with a greater or less bend to the East and West. If the cause producing this variation of heat be supposed to move round the sphere from East to West, then will every meridian in succession be subjected to alterations of currents from the East and West.

Effects of a communication of motion to the sphere.

(55.) Let us now suppose motion to be communicated to the sphere with an uniform velocity from West to East, that the force of gravity is equal, and for the present that centrifugal force produces no effect. Since this rotatory motion must be greatest at the Equator, and is directed Eastward, the air in its passage from the Poles, not having attained the maximum velocity, will have a relative motion Westward; and hence the motion of the wind in the Northern hemisphere will be from North-East to South-West, and in the Southern hemisphere from South-East to North-West. Whenever this apparent tendency coincides with an actual impulse in the same direction, derived from other sources, it will augment its force; and when opposed to one in a contrary direction, it will tend to neutralize it. Thus, in the supposition which has been just made, of an accession of temperature through the entire range of any meridian, the current, which we found would thence arise from the East towards that meridian, would be increased by this further mechanical impulse; while the Western current acting on the opposite side would be decreased, if not annihilated.

But as the lower Polar current would thus have a relative Westerly direction, with regard to the motion of the sphere itself, so the upper Equatorial current would have an absolute movement in the contrary direction. The particles of air, which are transported from the Polar regions to the Equator, have not time to assume the velocity of the different parallels of latitude as they reach them; and are, therefore, necessarily behind as they revolve. To other bodies, therefore, possessing that velocity, they oppose a resistance which appears to proceed from the Eastern quarter. Those, however, which are transported above from the Equator to the Poles, have an excess of absolute motion from West to East above those parts of the globe towards which they are carried. And as the heating power, which is the source of all the motions of the imaginary atmosphere, is in the sphere itself, it follows that the upper parts, which are most remote from it, will become cooled; while those which are nearer to, or in contact with it, maintain their proper temperature. As they cool they of course become specifically heavier and descend; their place being supplied by the subjacent warmer strata. Another kind of circulation becomes thus established in a direction perpendicular to the horizontal currents; and if we contemplate the motion of a single particle of air, we shall find that it maintains an angular course, in a direction compounded of these two motions. The upper Equatorial current having also a movement of rotation from West to East, greater than that of the Polar latitudes towards which it is carried, the effect must be felt by the particles in their descent from the higher to the lower stream, and the consequence will be, that the latter will be deflected from its course, the Northern current receiving a Westerly direction at the point where this influence reaches its stream with sufficient power.

We shall now proceed to the second part of Mr. Daniell's inquiry,

On the Habitudes of an Atmosphere of Pure Aqueous Vapour.

Atmosphere of vapour surrounding a sphere covered with water, of uniform temperature

(56.) This atmosphere of vapour must be first contemplated as surrounding a sphere entirely covered with water, and of uniform temperature throughout. This temperature is limited by Mr. Daniell to 32°, as in his first hypothesis of the permanently elastic fluid.

(57.) The elastic force of steam, for the different degrees of heat within the range of atmospheric temperature, has been determined with great precision by Mr. Dalton; the results of which may be seen in the Table at p. 333 of our *Essay on* HEAT. According to that Table, with a temperature of 32°, the equivalent column of mercury would be .200 inch, which would moreover be the same at every point of the spherical surface. The density of the vapour, like that of the gaseous atmosphere, must diminish in a geometrical ratio for equal elevations, and the temperature also will decline proportionally with it. The ratio, however, of its diminution will be of a different value. Mr. Daniell then traces the decrease of density and temperature in an atmosphere of aqueous vapour, of the force alluded to, at different elevations; and infers, that with such an arrangement, there would be a perfect equilibrium in the aqueous mass in all points of the sphere. Neither would precipitation or evaporation take place, but the atmosphere would remain transparent and undisturbed. Such also must be the state to which an atmosphere of vapour would tend, notwithstanding any obstacles that might be presented to oppose it. And hence also Mr. Daniell infers, that, if condensation were to take place in any part of an atmosphere so constituted, evaporation must also take place to maintain the equilibrium; and conversely, that evaporation must be accompanied by precipitation.

(58.) Should the temperature of the sphere rise gradually and uniformly over every part of its surface, the elasticity of the steam would increase without any disturbance; and obeying its own law of decrease for different elevations, it would remain perfectly transparent.

Effects of an elevation of temperature from the Poles to the Equator.

(59.) In considering again, with Mr. Daniell, the second condition, namely, that of an elevation in the temperature of the sphere from the Poles to the Equator, it may first be remarked, that a pure unmixed atmosphere of vapour could by no means render itself obedient to such a law. The elasticity of the whole would be measured by that of the lowest point; and the water would distil from the hottest to the coldest point with such a rapidity, as to occasion a strong ebullition at the former. The condensation of vapour may be effected not only by decrease of temperature, but by an increase of pressure; it is not necessary, therefore, that it should pass from the hottest to the coldest point to be precipitated, which would be a gradual process; but the elastic force, arising from an increase of density at one extremity, would instantly be felt at the other, Illustrated by Wollaston's Cryophorus.

the impression being conveyed as through a spring. Mr. Daniell illustrates this effect by the beautiful Cryophorus of Dr. Wollaston, in which the force of the vapour is so much reduced by the cold applied to one extremity of the instrument, as speedily to produce congelation at the other by the rapidity of the consequent evaporation. The rapidity of action is, however, not necessary for the present investigation; for we must imagine the passage of heat from one point to another to be so mechanically retarded, as to enable it to assume all the gradations due to the heat of the sphere. This will enable us to estimate the relative force and pressure of two of the vertical columns at different stations; and Mr. Daniell having computed the decrease of density and temperature in an atmosphere of aqueous vapour of the force of 1.00 inches, at different elevations, observes, that unlike the case of the permanently elastic fluid, both the density and elasticity will be found greatly to increase with the temperature; and that therefore the Equatorial columns must press upon the Polar columns throughout their entire length. A circulation will hence arise very different from that of the aerial currents. The vapour would flow in a mass from the Equator to the Poles; and being necessarily condensed in its course, would return from the Poles to the Equator in the form of water. Great evaporation would be constantly going on at the latter station, and condensation at every other; so that the atmosphere, excepting at the Equator, would be rendered turbid by perpetual clouds and rain. As in the case of the permanently elastic fluid, the temperature of the sphere would by this process soon become equalized, did not our hypothesis provide for its permanency: the Equatorial parts would become quickly cooled by the evaporation, and the Polar become warmed by the heat evolved during the process of condensation.

(60.) It is further worthy of attention, that the elasticity of vapour increasing nearly in a geometrical proportion for equal increments of heat, the decrease of temperature in ascending in this atmosphere will be in arithmetical proportion only; the diminution being nearly three degrees for every 5000 feet.

(61.) Upon the hypothesis of the gradation of temperature before assumed, in the case of the gaseous atmosphere, Mr. Daniell furnishes the following Table to represent the corresponding elasticity and density of the vapour at the surface of the sphere, for every ten degrees of latitude.

Illustrative Table.

TABLE VIII.—*Showing the Force and Density of an Atmosphere of Aqueous Vapour, for every Ten Degrees of Latitude, surrounding a Sphere unequally heated.*

Poles.			Latitude 80.			Latitude 70.			Latitude 60.			Latitude 50.		
Elast.	Density.	Temp.	Elast.	Density.	Temp.	Elast.	Density.	Temp.	Elast.	Density.	Temp.	Elast.	Density.	Temp.
.064	0.340	0	.072	0.380	3.2	.089	0.466	9.6	.125	0.641	19.2	.200	1.000	32

Latitude 40.			Latitude 30.			Latitude 20.			Latitude 10.			Equator.		
Elast.	Density.	Temp.	Elast.	Density.	Temp.	Elast.	Density.	Temp.	Elast.	Density.	Temp.	Elast.	Density.	Temp.
.351	1.700	48	.539	2.547	60.8	.731	3.403	70.4	.900	4.143	76.8	1.000	4.571	80

The temperature of some Latitude increased to that which adjoins it.

(62.) Let us next imagine, that the temperature of any particular latitude is raised to the level of that which adjoins it. This will cause condensation to cease at that point, evaporation to commence, and the atmosphere to become transparent. The quantity of water precipitated will be proportionally increased on the other side. But if, on the contrary, the temperature of the parallel be lowered to that of the parallel next above, the precipitation will be increased, and the higher latitude be cleared of its turbid matter. The next Table represents the condition of Latitude 30 under these interesting circumstances.

Illustrative Table.

TABLE IX.—*Showing the State of the Atmospheres arising from Alterations of Temperature in any intermediate Columns.*

Latitude 40.			Latitude 30.			Latitude 20.		
CLOUDY.			CLEAR.			CLOUDY.		
.351	1.700	48	.731	3.403	70.4	.731	3.403	70.4
CLEAR.			CLOUDY.			CLOUDY.		
.351	1.700		.351	1.700		.731	3.403	70.4

Effects of Evaporation

(63.) Again, if the mechanical retardation of the flowing vapour were subject to variation, the quantity of evaporation and precipitation would be proportionate to the velocity of its passage: thus, supposing the evaporation from a given surface at a given temperature, and under a given resistance, to be three grains per minute, that quantity would be doubled with half the resistance. The changes at the surface affect the whole of the superincumbent column equally, and the temperature of the vapour follows its own particular law of decrease. But what, says Mr. Daniell, will be the consequence, if the vapour should be forced to adapt itself to a progression of temperature different from its own; and if, from some cause, the heat of the upper regions should diminish at a greater rate than is due to its natural gradation?

(64.) Let us, for instance, suppose that the heat of the water upon the surface is 80°, but that at the height of 5000 feet above the surface, a temperature exists of only 64°.4, which from that point follows the former decreasing scale. The water in such a case will have a tendency to throw off vapour of the same constituent heat as its own temperature; but the pressure above, being rendered too little by the influence of the forced degree of cold, to preserve the necessary elasticity below, the atmosphere will only possess the tension due to the lower degree; that is to say, the constituent temperature of the vapour will be only 67°.9. Evaporation must therefore ensue below, and its concomitant precipitation above. The calculation of these effects is entered in the next Table.

Illustrative Table.

Table X.—*Showing the Effect upon the Atmosphere of Vapour of a forced gradation of Temperature.*

Height.	Elasticity.	Constituent Temp. of Vapour.	Sensible Temp.	State of Atmosphere.
0	.673	67.9	80	Clear
5000	.606	64.4	64.4	Cloudy
10000	.542	61	61	Clear
15000	.490	58	58	"
20000	.443	55	55	"
25000	.401	52	52	"
30000	.363	49	49	"

Formation of a Cloud.

(65.) The consequence of this supposition will be, that a Cloud will be formed at the height which has been named; for the atmosphere will be forced upwards by the nascent vapour existing below, and a condensation at this point will ensue. The Cloud, however, supposing the process to be sufficiently gradual, would not extend very far below, because the water, during its precipitation, would be redissolved by the excess of heat in the lower regions, so that they might remain transparent and undisturbed. The ultimate effect would be, that the temperature would be slowly equalized, and the balance of force restored. The water, in its circulation backwards and forwards, would act as a carrier of the heat, which it would abstract from the lower parts by its evaporation, and give out to the upper by its condensation. The atmosphere would thus gradually recover its state of equilibrium and repose, the upper regions remaining clear, because the gradation is there undisturbed.

Effects of the diminution of temperature throughout an entire column.

(66.) The sudden decrease of heat need not, however, be confined to a single point; but may be supposed to continue throughout the entire column, and to adapt itself to some progression. Instead also of its being limited to a single vertical atmospheric column, it may be taken in connection with other adjacent sections. As an example, Mr. Daniell gives the annexed Table, adapted to the Equator with a temperature of 80°, and the parallel of 10°, with a temperature of 76°.8, and in which also the flow of the lateral currents is exhibited.

Illustrative Table.

Table XI.—*Showing the State of the Atmosphere occasioned by the Intermixture of Lateral Currents.*

Height.	Latitude 10.				Latitude 0.			
	Sensible Temp.	Constit. Temp.	Elast.	State of Atmos.	Sensible Temp.	Constit. Temp.	Elast.	State of Atmos.
0	76.8	51	.388	Clear	80	67.9	.673	Clear
5000	61.1	48	.351	Clear	64.4	64.4	.606	Clear
10000	44.9	45	.316	Cloudy	48.4	19	.124	Clear
15000	27.7	12	.096	Clear	31.4	16	.112	Clear
20000	9.3	9.3	.087	Cloudy	12.8	12.8	.100	Clear
25000	−11.6	−32	.019	Hazy	− 7.6	−27	.027	Clear
30000	−35.	−35	.016	Hazy	−30.7	−30.7	.020	Clear

Remarks relating to the last Table.

(67.) In the Equatorial division of the Table, the first point of condensation is supposed to take place at the height of 5000 feet, while, in the other division, it is limited to 10,000 feet; and it will be perceived, that up to the former elevation, the vapour of the first column is of much greater elasticity and density than that of the latter, and that it must consequently flow towards it with considerable force. No Cloud, however, will be formed, as before, at the point of condensation, because the supply arising from the evaporation at the surface, will be carried off in a lateral direction, or, if previously formed, would soon be dissipated by the same operation. Nor would the transparency of the parallel of 10° be affected up to this height; for the current which it would receive would, in its constituent temperature, still be below what its sensible heat would maintain. But above this line a dense Cloud would be precipitated. A counter flow of small extent towards the Equator will be established at the altitude of 10,000 feet; and above this, again, the pressure will return to the first direction. The constituent temperature of the returning current being below the temperature of the elevation, the transparency of the Equatorial column will be preserved throughout.

Case where the water is only partially diffused, the uncovered portions being dry.

(68.) The preceding hypotheses have been framed upon the assumption, that the sphere round which the aqueous atmosphere has been diffused, was covered entirely with water, from which a continual supply of vapour would flow, equivalent to every circumstance of temperature. Let us now suppose, with Mr. Daniell, that the water is only partially diffused, and that the uncovered portions are absolutely dry. Vapour, not in contact with water, is known to be affected in the same manner as the permanently elastic fluids, by variations of temperature, its volume expanding or contracting $\frac{1}{480}$th part for each degree of change above its point of precipitation, by Fahrenheit's scale. If a current, therefore, were to pass over a dry space, of a higher temperature than itself, the same changes would take place, in miniature, as we have already traced in the dry atmosphere. Its density would diminish, while its elasticity would remain the same upon the surface, and be increased at all the higher stations. In the case of vapour becoming heated in this manner, out of the contact of water, it may reach its point of deposition at a high elevation without producing any sensible Cloud; for although it would be slowly precipitated, it would be instantly restored to the elastic form by the excess of heat in the inferior strata; and no accumulation could be formed for want of a supply from the dry surface below. A slight haziness might possibly be the result.

Effects of a stream of vapour passing from a part of the sphere covered with water to a part perfectly dry.

(69.) Let us now imagine, continues Mr. Daniell, a stream of vapour, of known density, filtering its way laterally, from one part of the sphere, which is covered with water of a certain temperature, to another which is perfectly dry, but of equal or superior temperature. As the vapour arrives at the dry space, it will be rapidly diffused; and its elasticity, being no longer confined by an incumbent atmosphere of like density, will be reduced, and will assume that force which its own diffusion will enable it to maintain. Or a stream of vapour, of high elasticity, flowing into a space where there already exists an atmosphere of inferior force, will be reduced in density to that of the general mean.

Case where the surface is differently embued with moisture and variously heated.

(70.) But the surface upon which an atmosphere of any particular density rests, may be neither water, nor yet perfectly free from it; it may be earth differently embued with moisture and variously heated. A partial supply of moisture, varying in quantity in different places, but of the same degree of density, would arise, and Clouds of more or less opacity would be formed, at corresponding situations, in the planes of deposition above. Mr. Daniell has calculated the following Table to illustrate these interesting positions.

Illustrative Table.

TABLE XII.—*Showing that the Elasticity of Vapour, yielded by different Surfaces variously heated, is governed by the incumbent Atmosphere.*

		Water, Temperature 60.8.			Moist Earth, Temperature 70.			Dry Earth, Temperature 80.		
Height.	General Temp.	Constant Temp.	State of Atmosphere.	Force of Evaporation.	Constant Temp.	State of Atmosphere.	Force of Evaporation.	Constant Temp.	State of Atmosphere.	Force of Evaporation.
0	60.8	34	Clear	.368	34	Clear	.507	34	Clear	786
5000	44.6	31	Clear	Density	31	Clear	Density	31	Clear	
10000	27.9	28	Cloudy	.368	28	Cloudy	.092	28	Hazy?	
15000	10.	– 6.4	Clear		– 6.4	Clear		– 6.4	Clear	
20000	– 9.4	– 9.4	Cloudy	.126	– 9.4	Hazy	.021	– 9.4	Clear	
25000	–31.2	–31.2	Hazy	.020	–31.2	Clear		–31.2	Clear	
30000	–55.9	–55.9	Clear		–55.9	Clear		–55.9	Clear	

(71.) This atmosphere, which is supposed to be of equal force in every part, and in which the same general temperature prevails, rests upon a surface covered with water in one part, with moist earth in another, and on a dry surface in a third. The first point of precipitation is placed, it will be perceived, at 10,000 feet. The water upon which the first part of the column rests, is of the same degree of heat as the general temperature at the surface. The force of evaporation is estimated by Mr. Daniell at 368, and the supply being equal to the force, the density of the Cloud is denoted by the same number. The moist earth upon which the second portion rests, is of the temperature of 70°, which makes the force of evaporation 507; but less steam being given off from the earth than from the water, the quantity precipitated is proportionally diminished. In the Table, Mr. Daniell has estimated it at one-fourth. The dry surface of the earth, which supports the third portion, being heated to 80°, yields no vapour; the evaporating force, which is equal to 786, is wholly unapplied, and no Cloud can therefore be maintained. The higher points of the atmosphere are subject to similar modifications. The temperature of the evaporating surface regulates the quantity of water raised in vapour, and the tension of the pre-existing atmosphere determines its elasticity.

We shall now proceed to the consideration of Mr. Daniell's third division of his inquiry, *viz.*

On the Habitudes of an Atmosphere of permanently elastic fluid, mixed with aqueous vapour.

Consideration of the case of an atmosphere of permanently elastic fluid, mixed with aqueous vapour.

(72.) The properties which each possessed in its separate state, will be retained in this connection unchanged; and the two fluids will exercise no further action upon each other, than a mechanical opposition when in motion. The particles of steam, in penetrating the interstices of the permanently elastic fluid, experience the same species of retardation, as may be supposed to exist, if they flowed through the pores of sand or cotton. When an equilibrium is attained, this mutual action ceases, and the particles of each press only upon those of their own kind. There are, therefore, continues Mr. Daniell, two principal points of view under which such a mixture may be regarded; first, that in which the particles are in a state of perfect equipoise amongst themselves; and, secondly, where they are seeking to attain an equilibrium by means of intestine motion. With respect to the first, there is no distinction between such a complete mixture, and that of two or more permanently elastic fluids; and it may be regarded like a mixture of gases, as an homogeneous fluid.

Conditions of such an atmosphere when surrounding an atmosphere of uniform density.

(73.) Let us now inquire what would be the natural condition of such an atmosphere, when surrounding a sphere of uniform temperature throughout.

The first effect of mixing known measures of gases, with vapour of different degrees of force, is to produce an increase of bulk, under an equal pressure in the permanently elastic fluid; not, however, in proportion to the measure of the vapour communicated to it, but in proportion to its elasticity. The second result is, that the Specific Gravity of the gas is diminished, but not exactly in proportion to its expansion; for while the atoms constituting the vapour are all dilated, their own weight is added to the mixture. But this weight, though increasing with the elasticity, being, in all cases, less than that of an equal bulk of common air, a decrease of density must follow. This diminution of temperature becomes greater with every increment of temperature.

Progress of vapour in a perfectly dry atmosphere.

(74.) To place all the circumstances connected with this interesting subject in a clear point of view, let us, continues Mr. Daniell, trace the progress of vapour just beginning to form in a perfectly dry atmosphere. For this purpose, let the temperature of the sphere be 77°. The first arrangement will be the same as that represented under the parallel of 10° in Table I. If we now suppose water suddenly to overflow the surface, evaporation will instantly commence. No atmosphere of vapour exists to impede its progress, and the nascent steam will merely assume such a degree of tension, as is necessary to overcome the *vis inertiæ* of the air which obstructs its motion. What this force may be, we have not, perhaps, sufficient data to determine. For the present, we must give to it an arbitrary value, and assume, that, at the temperature of 77°, and pressure of 30 inches, it amounts to .200 of an inch. The constituent heat of vapour of this elasticity is 32°, so that at the height of 13,500 feet it arrives at its point of condensation. An aqueous atmosphere of such a degree of force being now established, a resistance proportioned to this amount is made to the progress of evaporation; and the elasticity of the rising steam must in consequence be doubled. Its constituent temperature, therefore, by Table V. p. 333 of our *Essay on* HEAT, is raised to 52°, and it cannot pass the height of 7500 feet without decomposition. The resistance upon the surface now amounts to .601 inch, to overcome which, vapour at 65° must be emitted. The first point of precipitation, in ascending from the surface, would thus be fixed at about 3600 feet; and it may now further be remarked, that the diffusion of vapour does not cease at the height of 3500 feet, to which point we had first traced it, but that the mechanical obstruction is proportionably reduced, and is carried by successive stages to loftier regions, where its tenuity is so much increased, that it rapidly eludes all observation.

Points of condensation.

(75.) With regard to the various points of condensation, it is probable, continues Mr. Daniell, that, as in the atmosphere of pure steam, no cloud will be formed at any of them. The process of evaporation would be so gentle under these circumstances, that little above six grains of water would be raised per minute from a square foot of surface; so that, as the gradual precipitation of this quantity took place between the different stages, it would instantly be redissolved by the excess of heat into which it would be naturally inclined to fall. The circulation thus becomes a process of equalization, by which the temperature of the upper regions is raised: the heat which is abstracted below by evaporation is evolved by condensation, the pressure of the vapour becomes increased, and all the changes tend to that peculiar distribution of heat, which we before contemplated as the natural state of an unmixed atmosphere of steam.

Approximation to the quantity of vapour which would exist upon such an hypothesis.

(76.) The average quantity of vapour which would exist upon the hypothesis we have just assumed, while the atmosphere maintained its proper progression of temperature may be roughly approximated as follows:—A stratum, of the force of .616 inch, extends to the height of 3600 feet; another, of the force of .401 inch, reaches 3900 feet higher; a third, of only .200 inch, stretches almost as far as both the former together; making a total of 13,500 feet. The mean, therefore, to this point is nearly $\frac{.616}{4}+\frac{.401}{4}+\frac{.200}{2}=.354$ inch. For the further distance of 17,500 feet, Mr. Daniell thinks we cannot greatly err in taking .064 inch, as the mean pressure, making the average to the height of 31,000 feet, .209 inch. One-third of the atmosphere beyond this being considered free from vapour, reduces the mean to .139 inch.

Change of hypothesis to that of a sphere whose temperature increases from the Poles to the Equator.

(77.) Changing now our hypothesis of a sphere of uniform temperature, for one whose temperature increases from the Poles to the Equator, let us assume that the Barometer stands every where upon its surface at the constant height of 30 inches. The constituent temperature of the vapour, also, in the different columns of this mixed atmosphere, at the surface of the sphere, is to approach to within eleven degrees of the temperature of the several zones. The succeeding Table has been calculated by Mr. Daniell, to develope the consequent arrangements.

TABLE XIII.—*Showing the Specific Gravity, Elasticity, Temperature, and Dew Point, of a mixed Atmosphere of Air and Aqueous Vapour, at different Altitudes and different Latitudes from the Pole to the Equator.*

	Poles.					Latitude 80.					Latitude 70.					Latitude 60.					Latitude 50.				
Height.	Total Pressure.	Pres. of Vap.	Specific Gravity.	Temp.	Dew Point.	Total Pressure.	Pres. of Vap.	Specific Gravity.	Temp.	Dew Point.	Total Pressure.	Pres. of Vap.	Specific Gravity.	Temp.	Dew Point.	Total Pressure.	Pres. of Vap.	Specific Gravity.	Temp.	Dew Point.	Total Pressure.	Pres. of Vap.	Specific Gravity.	Temp.	Dew Point.
0	30.000	.044	1.06666	0	−11	30.000	.047	1.06038	3	− 8	30.000	.057	1.04685	9	− 2	30.000	.085	1.02607	19	8	30.000	.134	.99835	32	21
5000	23.597		.86935	− 18		23.652		.86542	− 15		23.707	.033	.85684	− 8	−17	23.793	.047	.84427	1	−8	23.949	.079	.82563	14	6
10000	18.587		.70856	− 37		18.630		.70637	− 34		18.724		.70140	− 27		18.893		.69405	− 17		19.106	.045	.68321	− 3	− 9
15000	14.591		.57752	− 58		14.642		.57654	− 55		14.775		.57407	− 47		14.969		.57061	− 36		15.229		.56472	−22	
20000	11.411		.47071	− 82		11.484		.47057	− 78		11.617		.46991	− 70		11.827		.46904	− 58		12.044		.46677	−43	
25000	8.900		.38365	−109		8.965		.38408	−104		9.102		.38463	− 96		9.314		.38558	− 83		9.579		.38582	−67	
30000	6.906		.31270	−140		6.978		.31352	−135		7.100		.31483	−126		7.302		.31699	−112		7.566		.31890	−95	

	Latitude 40.					Latitude 30.					Latitude 20.					Latitude 10.					Equator.				
0	30.000	.237	.96358	48	37	30.000	.375	.93463	61	50	30.000	.507	.91278	70	59	30.000	.616	.89764	77	65	30.000	.698	.89018	80	69
5000	24.072	.139	.80230	31	22	24.215	.221	.78245	44	35	24.279	.328	.76703	54	46	24.319	.401	.75621	61	52	24.342	.443	.75133	64	55
10000	19.338	.068	.66800	14	2	19.531	.112	.65503	28	16	19.675	.162	.64489	38	26	19.738	.200	.63762	45	32	19.779	.229	.63436	48	36
15000	15.525	.037	.55629	− 4	−14	15.739	.046	.54855	10	− 8	15.898	.068	.54180	20	2	16.012	.087	.53703	27	9	16.060	.100	.53520	31	13
20000	12·409		.46273	− 24		12.673	.034	.45856	− 9	−17	12.811	.046	.45500	1	− 8	12.974	.064	.45147	9	0	13.043	.071	.45068	12	3
25000	9.915		.38489	− 47		10.162		.38327	− 31		10.342		.38166	− 19		10.467	.015	.38010	− 11	−35	10.521	.032	.37980	− 7	−16
30000	7·852		.32016	− 62		8.135		.32035	− 56		8.313		.32010	− 43		8.424		.31948	− 35		8.483		.31980	−30	

Specific Gravity and elasticity of the air but slightly influenced by the intermixture of the aqueous vapour.

(78.) By comparing the results contained in this Table with those recorded in Table I., it will be seen, that the Specific Gravity and elasticity of the air is but very slightly influenced by the intermixture of the aqueous vapour; so slightly, indeed, that the course and velocity of the currents, as represented in Table II., may with safety be adopted, without producing any sensible error in the investigation. Their balance also is to be that by which the Barometer is maintained at an unvarying height. It will also be remarked, that while the great aerial ocean is divided into two great strata, flowing in opposite directions from North to South, and South to North, the aqueous part, which is nearly confined to the lower current, presses in a contrary direction. The adjustment of these particulars remaining as now supposed, the compensating winds flow on in the courses which have been described, and the balance remains undisturbed.

Evaporation will affect the gradation of temperature resulting from the decreasing density of the upper parts of the atmosphere.

(79.) The admixture of vapour, hitherto considered, has not yet affected the gradation of temperature, resulting from the decreasing density of the atmosphere in its upper parts, but the process of evaporation must in time necessarily induce such an alteration. The steam, as it reaches its point of condensation, must give out its latent heat, and, during its precipitation, combining with a fresh proportion, it must again ascend, and again be evolved in the middle regions. The atoms of steam may thus be considered as carrying caloric from the surface of the sphere to the higher strata; and it is obvious how a considerable section of any one column may thus have its temperature equalized and fully saturated with aqueous particles. The currents thus become affected both by the expansive power of the vapour and of the liberated heat;—causes, the influence of which so applied, must be partial, and cannot reach the higher regions. This unequal action must produce a fall in the Barometer.

Effects on the Barometer.

(80.) Again, as, on the one hand, this effect upon the Barometer is produced by the augmentation of the quantity of aqueous vapour, so, on the other, a rapid increase of the latter may be produced by a fall in the former. The mechanical resistance of the air must of course be increased by its motion in opposition. When this is stopped, as it soon is, by any small diminution of the mercurial column, the vapour will rush forward with its whole force, retarded only by the kind of filtration which must take place through the quiescent air; and the temperature of the higher latitude being unable to support its elasticity, precipitation must follow. From the operation of these causes, the temperature of the latitude will be partially affected, the density of the air be still further reduced, and the aerial column become reversed. The course of the vapour being thus greatly accelerated, an abundant precipitation must follow.

Precipitation of moisture.

Further effects of precipitation.

(81.) The progress of the precipitated moisture, from the time when its first streaks would be found to shoot in a visible form across the atmosphere, to the period when it descends in rain upon the globe, is not without its interest. In proportion to the density of the vapour, must be the magnitude of the condensed particles. When first formed in the higher regions, the cloud would probably assume a light *cirriform* appearance, but at lower elevations, their precipitation would be more dense, and the attraction of aggregation stronger. The mass would thus gently subside to a lower station, where the density of the air would oppose a greater resistance to its descent. Here, in a higher temperature, the cloud would begin again to be dissolved, and assume a rounded and more compact form, and thus the equalization of the temperature, and the diffusion of the vapour, would be carried on from several points at once. The different beds obey the impulse of the winds, and, as they sail along, enlarge the sphere of their action, till, at length, the natural equilibrium of the atmosphere can be no further checked. Hence precipitation will increase, the strata of the clouds unite, and the air no longer be capable of buoying up their load.

Force of the aerial currents between the Poles and Equator.

(82.) In the next Table Mr. Daniell furnishes us with a view of the force of the aerial current, and the counter pressure of the vapour in a mixed atmosphere, surrounding a sphere unequally heated in the manner already set forth.

Table XIV.—*Showing the Force of the different Currents in a Mixed Atmosphere of Air and Vapour, between the Poles and Equator.*

Height.	Latitudes 90 and 80.		Latitudes 80 and 70.		Latitudes 70 and 60.		Latitudes 60 and 50.		Latitudes 50 and 40.		Latitudes 40 and 30.		Latitudes 30 and 20.		Latitudes 20 and 10.		Latitudes 10 and 0.	
	Wind.	Vapour.	Wind.	Vapour.	Wind.	Vapour.	Wind.	Vapour.	Wind.	Vapour.	Wind.	Vapour.	Wind.	Vapour.	Wind.	Vapour.	Wind.	Vapour.
0	+.178	–.003	+.387	–.010	+.575	–.028	+.810	–.049	+1.034	–.103	+.854	–.138	+.648	–.132	+.447	–.109	+.208	–.082
5000	+.057		+.191		+.281	–.014	+.375	–.032	+.570	–.060	+.454	–.082	+.392	–.107	+.282	–.073	+.118	–.042
10000	+.019		+.048		+.045		+.112		+.217	–.023	+.215	–.044	+.165	–.050	+.159	–.038	+.053	–.029
15000	–.023		–.063		–.093		–.084		–.035		+.031	–.009	+.038	–.022	+.036	–.019	+.008	–.013
20000	–.069		–.112		–.185		–.149		–.239		–.131		–.024	–.012	–.068	–.018	–.045	.007
25000	–.078		–.152		–.240		–.272		–.307		–.196		–.128		–.074		–.054	
30000	–.095		–.161		–.264		–.321		–.322		–.291		–.170		–.090		–.070	

Difficulties respecting the resistance offered to the passage of the aqueous vapour by the gaseous constituents of the atmosphere.

(83.) We have already stated our difficulties, with regard to the amount of resistance which the pores of the gaseous constituents of the atmosphere offer to the passage of the vapour in motion. Experiments are wanting to elucidate this subject, but the observations of Saussure and Dalton throw some light upon the subject. The resistance here alluded to may be regarded as twofold; first, in connection with the permanently elastic fluid at rest, and secondly, with it in motion.

(84.) With regard to the state of rest, the opposition with which vapour passes through air, is in proportion to its density. Saussure concluded from his experiments, that a diminution in the density of one-third doubled the rate of evaporation.

(85.) With respect to motion, a breeze acting in opposition to the stream of vapour, must retard its progress as much as one in the same direction favours it. Much obscurity, however, envelopes this inquiry, from the vagueness of the terms employed in denoting the velocity of the air. Mr. Dalton has determined that the rate of evaporation, in a perfect calm, being denoted by 120, that of a brisk wind is 154, and of a high wind 189. The retardation of opposing currents of the same respective forces, may therefore be reckoned in proportion.

Velocity with which aqueous vapour travels.

(86.) It is impossible, in the present state of our knowledge, continues Mr. Daniell, to determine the absolute velocity with which vapour travels under any of the circumstances mentioned; but the relative rates of different parts of the same column may be approximated.* Thus, taking as an example the latitude of 30 laid down in the last Table, the current which blows in the direction of the parallel of 40 may be deemed high, and retards the motion of the vapour towards latitude 20 accordingly. At the elevation of 10,000 feet, the density of the air is reduced one-third, and the velocity is consequently doubled. To this must be added the consideration, that the opposing current, at the same elevation, declines in strength, thereby increasing the force in the still higher ratio of 189 to 154. More vapour, therefore, would probably pass at this elevation than at the surface, although its excess of elasticity is only .044 inches at the former station, and .138 inches at the latter. Whenever a deep stratum of air has had its temperature and vapour equalized, in the manner before described, it is easy to conceive that the aqueous atmosphere may travel in its upper parts with considerable velocity, in a course directly opposed to the wind at its lower. The approximation, however, has been carried a little further by Mr. Daniell. The effect of a brisk wind, in accelerating evaporation, is equal to an increase of about three-tenths of the elasticity, that of a high wind being six-tenths. The retarding influence of the Polar current, in its regular state, may therefore be apportioned to the different latitudes in Tables XIII. and XIV., as follows:

From the Poles to latitude 80 = $\frac{1}{10}$ of the elasticity, to latitude 70 = $\frac{2}{10}$, latitude 60 = $\frac{4}{10}$, latitude 50 = $\frac{6}{10}$, latitude 40 = $\frac{6}{10}$, latitude 80 = $\frac{5}{10}$, latitude 20 = $\frac{3}{10}$, latitude 10 = $\frac{2}{10}$, and from latitude 10 to the Equator $\frac{1}{10}$. The following Table will then represent the efficient force of the vapour in a lateral direction, calculated for the surface of the sphere, and for the altitude of one-third the density.

TABLE XV.—*Showing the efficient lateral force of Vapour between the Poles and Equator at the Surface of the Sphere, and at the Altitude of one-third the Density.*

	Latitudes 90 and 80.		Latitudes 80 and 70.		Latitudes 70 and 60.		Latitudes 60 and 50.		Latitudes 50 and 40.		Latitudes 40 and 30.		Latitudes 30 and 20.		Latitudes 20 and 10.		Latitudes 10 and 0.	
Height.	Balance of Force.	Effects of Wind and Density.	Balance of Force.	Effects of Wind and Density.	Balance of Force.	Effects of Wind and Density.	Balance of Force.	Effects of Wind and Density.	Balance of Force.	Effects of Wind and Density.	Balance of Force.	Effects of Wind and Density.	Balance of Force.	Effects of Wind and Density.	Balance of Force.	Effects of Wind and Density.	Balance of Force.	Effects of Wind and Density
0	–.003	–.002	–.010	–.008	–.028	–.017	–.049	–.025	–.103	–.042	–.138	–.069	–.132	–.093	–.109	–.086	–.082	–.074
10000	–.001	–.002	–.004	–.008	–.008	–.017	–.012	–.026	–.023	–.045	–.044	–.072	–.050	–.090	–.088	–.070	–.029	–.058

This last Table, Mr. Daniell remarks, will give some idea of the retardation of force, in the vapour, occasioned by the wind, at the surface of the sphere, and also of the increase of velocity occasioned by diminished pressure in the upper regions. It is easy to understand that, whenever the aerial current coincides with the direction of the vapour, the progress of the latter is accelerated in the same proportion.

(87.) The permanency of the Barometric pressure, on the surface of the sphere, is dependent, as already remarked, upon the equal balance of the aerial currents; and its fluctuations have been traced to the destruction of this equipoise, by unequal and local expansions and condensations. One of the chief causes of these latter, Mr. Daniell attributes to the increase and decrease of the aqueous vapour, counteracting the natural progression of temperature by the caloric evolved in its condensation. But there is another cause, which must exercise a powerful influence, and to which no allusion has yet been made. It has hitherto been supposed, for the sake of simplifying the subject, that the source of heat has been in the sphere itself, and that all the regular changes of temperature emanate from its surface. This so far agrees with the condition of the atmosphere of the earth, with which it is Mr. Daniell's final object to identify his different hypotheses; for while in a transparent state, the sun's rays pass through the air without materially affecting it, and exhaust their influence upon the surface of the globe. But if the atmosphere become cloudy and opaque, the rays of heat, emanating from an externa source, are in great part absorbed before they reach the surface, and an increase of temperature and elastic vapour must take place in the middle regions. Here arises another source of partial and powerful expansion. To this also may be added the property which

Effects of cloudy an opaque st of the atmosphere on the temperat

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* Mr. Herschel, at page 51 of the third volume of the *Transactions of the Astronomical Society*, has the following remarks:—"On the night of the 19th of April, the sky had continued perfectly cloudless, with not a breath of air stirring, and a dew so copious as to run off the telescope in streams till about half past two A. M. I had to take the transit of 25 Herculis as a settling star, which passed at 16 hours 21 minutes, (per Chron.) At 16 hours 8 minutes, one of Piazzi's stars passed, and was taken; after which I continued sweeping, the heavens continuing beautifully clear. About 5 minutes before the expected passage of 25 Herculis, I noticed a dusky cloud bank in the East; it advanced rapidly. Immediately before the transit, Arcturus was completely invisible: while yet in the act of bisecting my star, the edge of the haze was on it, and in less than three minutes from that time had extended to the Western horizon, obliterating every star by a thick uniform coating of cloud. All the time the calm remained quite undisturbed. The least supposable rapidity of propagation in this case is 300 miles an hour, in the direction of the Sun's motion; and the cause is obviously the exact attainment of a determinate temperature in the region of the atmosphere, where the cloud formed, either by radiation, or by a diminution of atmospheric pressure taking place in succession along the whole zone of sky, and as it were pursuing the point of the heavens opposed to the Sun."

the clouds possess of preventing the radiation of heat from the surface beneath them, and the greater conducting power of damp, than of dry air.

Effects of further inequalities in the surface of the sphere.

(88.) Amongst the numberless modifications of condition, to which an atmosphere of the nature we have been considering is liable, there are yet two or three to which it will be necessary shortly to refer. The surface of the sphere has hitherto been chiefly considered as perfectly plain, and either thoroughly dry or everywhere covered with water. Let us now contemplate it as covered with water to the extent of three-fourths of its surface, and the remaining fourth of dry earth, uneven and intersected by eminences; conditions which assimilate it still more closely to the actual terrestrial atmosphere. Such an intermixture of land and water must at once introduce inequalities of temperature of a different character from those which have been hitherto considered. These will arise chiefly from the greater rapidity both of heating and cooling, in the dry surface, dependent upon the peculiar constitution of the watery element. As the processes by which their impressions are communicated to the incumbent air are slow and gradual, they mostly affect the different columns in an equable manner; so that their influence upon the atmospheric currents resolves itself into the cases which have been already proposed, of total and regular expansion. With respect to the vapour, however, the case is different. The parts of the atmosphere above the dry spaces cannot remain free from its admixture, because the elasticity of the surrounding medium will soon supply the vacuum. The law of this equalization will depend upon the mechanical obstruction of the air, which is influenced also by the conditions of the wind. When once diffused over the land, it will be more subject to condensation; and the amount of precipitation must be restored from the great expanse of waters.

(89.) Finally, unevenness of surface will tend, says Mr. Daniell, to modify the atmosphere in some minor degree. Any elevation will obviously partake of the temperature due to the stratum of air into which it may rise; but the action must be reciprocal; and as the heating surface is raised to higher regions, those regions must be proportionally and unequally affected.

We shall now pass to the consideration of some of the phenomena connected with the actual atmosphere of the earth.

Figure of the Atmosphere.

Figure of the Earth's atmosphere.

(90.) The problem of the figure of the atmosphere is connected with some very refined and delicate points of analysis. Had the Earth been truly of a spherical form, and entirely at rest, every portion of the atmosphere surrounding it, would, by the action of gravity, have assumed a perfectly globular form. But any velocity of rotation imparted to the Earth, would be gradually communicated to the atmospheric strata that surround it; and the friction of these strata against each other, and against the surface of the body, would accelerate the slower motions, and retard the more rapid, till a perfect equality was established.

(91.) At its surface the atmosphere is only retained by its weight; and the form of this surface is such, that the force which results from the centrifugal and attractive forces of the body, is perpendicular to it. The atmosphere is flattened towards the Poles, and distended at its Equator; but this ellipticity has limits, and in the case where it is the greatest, the ratio of the Polar and Equatorial axes is as two to three.

Limit to the atmosphere first conceived by Kepler.

In the seventh chapter of the third Book of the *Mécanique Céleste*, Laplace has entered on the consideration of the figure of the atmospheres of the celestial bodies, with his usual generalization and skill.

On the Limits of the Atmosphere.

(92.) The existence of a definite limit to the altitude of the atmosphere was first conceived by Kepler; and he sought to determine its elevation by means of the duration of the twilight. By an ingenious and interesting process, which most writers on Astronomy explain, it is known to extend to between 40 or 50 miles above the Earth's surface, and even at that altitude it still continues to possess a density sufficient for refracting and reflecting the rays of light.

(93.) The authors* who have written, says Mr. Ivory,† on the height and figure of the atmosphere, have likewise assigned a boundary beyond which it cannot reach. But in this they have rather fixed a limit to the domain peculiarly belonging to the Earth, than reasoned upon any distinguishing properties of the atmosphere itself. If we conceive a body that circulates round the Earth by the force of gravitation, in the time of a diurnal revolution, the path which it describes will mark the limit whereat the centrifugal force arising from the rotatory motion of the Earth will just balance the opposite centripetal force. Therefore any body that participates in the rotatory motion common to all, if placed beyond the boundary we have mentioned, would continually recede from the Earth, and be eventually lost in the immensity of space; or, if placed within the same boundary, would fall to the common centre. The radius of the orbit described by the revolving body is about 25,000 miles, or something more than three diameters of the terrestrial globe. Now the air surrounding the Earth cannot reach so far, for if it did it would be continually dissipated; a supposition which is extremely improbable, since we are acquainted with no source from which a constant waste of so necessary a fluid could be supplied.

Dr. Wollaston's attempt to fix a definite limit to the atmosphere.

The first writer‡ who attempted, from Physical considerations, to fix a definite limit to the atmosphere, was Dr. Wollaston, in the *Philosophical Transactions* for 1822, who remarks in his interesting Paper, that, in attempting to estimate the probable height to which the Earth's atmosphere extends, no phenomenon caused by its refractive power in directions at which we can view it, or by reflection from vapours that are suspended in it, will enable us to determine it. From the law of its elasticity, which prevails within certain limits, we know the degrees of rarity corresponding to different elevations from the Earth's surface; and if we admit that air has been rarefied so as to sustain only $\frac{1}{100}$ of an inch Barometrical pressure, and that this measure has afforded a true estimate of its rarity, we should infer from the law, that it extends to the height of forty miles, with properties yet unimpaired by extreme rarefaction. Beyond

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* D'Alembert, *Opus*, tom. vi. Laplace, *Mécanique Céleste*, liv. iii. ch. vii.

† *Philosophical Transactions* for 1823.

‡ Mr. Cavendish communicated to Mr. Davies Gilbert, President of the Royal Society, in the year 1808, the substance of a very interesting investigation relative to the definite limits of the atmosphere; but this appears never to have been published.

this limit we are left to conjectures founded on the supposed divisibility of Matter; and if this be infinite, so also must be the extent of our atmosphere. For, if the density be throughout as the compressing force, then must a stratum of given thickness, at every height, be compressed by a superincumbent atmosphere, bearing a constant ratio to its own weight, whatever be its distance from the Earth. But if air consist of any ultimate particles no longer divisible, then must expansion of the medium composed of them cease at that distance, where the force of gravity downwards upon a single particle is equal to the resistance arising from the repulsive force of the medium.

Observations of Mr. Faraday.

(94.) Mr. Faraday, when alluding to the admirable argument of Dr. Wollaston, observes, that on passing upwards from the Earth's surface, the air becomes more and more attenuated, in consequence of the gradually diminishing pressure of the superincumbent part, and its tension or elasticity is proportionally diminished; and when the diminution is such, that the elasticity is a force not more powerful than the attraction of gravity, a limit to the atmosphere must occur. The particles of the atmosphere there tend to separate with a certain force; but this force is not greater than the attraction of gravity, which tends to make them approach the Earth and each other; and as expansion would necessarily give rise to diminished tension, the force of gravity would then be the strongest, and, consequently, would cause contraction, until the powers were balanced as before.

Views of Dr. Wollaston extended to the atmospheres of other bodies.

(95.) Dr. Wollaston, however, has not confined his inquiries to the Earth's atmosphere; and, in extending his views to the probable existence of atmospheres round other bodies, he properly remarks, that since the law of definite proportions discovered by Chemists is the same for all kinds of Matter, whether solid, fluid, or elastic, if it can be ascertained that any one body consists of particles no longer divisible, we then can scarcely doubt that all other bodies are similarly constituted; and that we must conclude, without hesitation, that those equivalent quantities, which we have learned to appreciate by proportional numbers, do really express the relative weights of elementary atoms, the ultimate objects of Chemical research.

Absurdity of attempting to discover an atmosphere of infinite divisibility around the Moon.

(96.) In the first place, the views entertained by those, who, believing in the existence of a terrestrial atmosphere of indefinite extent, sought to discover the existence of an atmosphere of a similar kind round the lunar spheroid, may, from the reasoning of Dr. Wollaston, be proved to be utterly fallacious. For, since the density of an atmosphere of infinite divisibility at the surface of the Moon would entirely depend on her gravitating force at that point, that density could not be greater than the density of our atmosphere at the point where the Earth's attraction is equivalent to the Moon's attraction at her surface. At this height, which by a simple computation is about 5000 miles above the Earth's surface, we obviously can have no perceptible atmosphere, and, consequently, should not expect to discern an atmosphere of similar rarity around the Moon.

Approach of Venus to the Sun proving that no atmosphere of infinite divisibility surrounds the latter.

(97.) In the next place, the approach of Venus to the Sun, if the latter body were surrounded by an atmosphere of infinite divisibility, might be reasonably expected to present some degree of retardation in her apparent motion; whereas, from the very precise and accurate observations of Captain Kater, no such retardation can be perceived. If we calculate at what apparent distance from the body of the Sun his attractive energy is equal to the gravitating influence at the surface of the Earth, it is there that his power would be sufficient to accumulate (from an infinitely divisible medium filling all space) an atmosphere[*] fully equal in density to our own, and, consequently, capable of producing a refraction of more than one degree in the passage of rays obliquely through it.

(98.) By considering the mass of the Sun as 330,000 times greater than that of the Earth, the distance at which his gravitating force will be equivalent to the force of gravity at the surface of the Earth, will be $\sqrt{330,000}$, or, in other words, about 575 times the terrestrial radius; and if the radius of the Sun be 111.5 times that of the Earth, then will the distance here referred to be $\frac{575}{111.5}$, or 5.15 times the solar radius. Now the Sun's apparent semi-diameter on the day of observation (May 23d) having been $15' 49''$, it follows that $15' 49'' \times 5.15 = 1^\circ 21' 29''$ was the distance from the Sun's centre, at which his gravitating force was just equivalent to the ordinary force of gravitation at the Earth's surface.

Strong confirmation afforded by the approach of Jupiter's Satellites t Jupiter, tha the atmosphere of that planet is not one of infinite divisibility.

(99.) But the approach of Jupiter's Satellites to that Planet, instead of being retarded by refraction, is well known to be perfectly uniform, till they appear in actual contact; showing that there is not that extent of atmosphere surrounding Jupiter, which that body should attract to itself from an infinitely divisible medium filling all space. For since the mass of Jupiter is full 309 times that of the Earth, the distance at which his attraction would become equivalent to the ordinary terrestrial gravity, must be as $\sqrt{309}$, or about 17.6 times the Earth's radius. And since his diameter is nearly eleven times that of the Earth, we shall have $\frac{17.6}{11} = 1.6$ times his own radius, for the distance from his centre, at which an atmosphere, equal in density to our own, should occasion a refraction exceeding one degree. To the fourth Satellite, this distance would subtend an angle of about $3^\circ 37'$; so that an increase of density equivalent to 3½ times the density of our ordinary atmosphere, would be more than sufficient to render the fourth Satellite visible to us when behind the centre of the Planet, and, consequently, to make it appear on all sides of the Planet at the same time, or rather as a luminous ring surrounding the entire disc of the Planet.

General conclusion of Dr. W laston respecting th finite extent of the Earth's atmosphere.

(100.) Now, though with regard to the argument respecting the Solar atmosphere, some degree of doubt may be entertained in consequence of the possible effects of heat which cannot be appreciated, it is evident that no error from this source can be apprehended in regard to Jupiter; and as this Planet has certainly not its due share of an infinitely divisible atmosphere, the universal prevalence of such a medium cannot be maintained; while, on the contrary, all the phenomena accord entirely with the supposition that *the Earth's atmosphere is of finite extent, limited by the weight of*

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[*] Such an atmosphere would, in fact, be of greater density on account of the far greater extent of the medium affected by the Solar attraction, although of extreme rarity; but the addition derived from this source, may be disregarded in the present estimate, without prejudice to the argument, which will not be found to turn upon any minute difference.

ultimate of atoms of definite magnitude no longer divisible by repulsion of their parts.

Mr. Ivory's views on the same subject.

(101.) Mr. Ivory, in a Paper in the *Philosophical Transactions* for 1823, on Astronomical Refractions, in treating of this highly interesting question, conceives a cylinder of air to extend indefinitely in a vertical direction, and to be divided into equal parts of a moderate length, so that the density of every division may be considered as uniform; and by abstracting the diminution of Gravity and the increase of the centrifugal force, which are inconsiderable at the distance of 200 or 300 miles from the Earth's surface, the weight of air in every portion of the cylinder will be proportional to its density. If now, continues Mr. Ivory, we admit the elastic force to be proportional to the density, as it would be in an atmosphere of uniform temperature, it will follow, that the weights of the several divisions of the cylinder will vary in the same proportion as their elasticities. But in the lowest part of the cylinder, the weight of the small quantity of air contained in one division, is incomparably less than its elastic force, which is an equipoise to the whole atmosphere; and the same thing will therefore be true of every portion of the cylinder, however high it is placed. Hence an atmosphere constituted as we have supposed, must necessarily be infinite in its extent. For if it were finite, since there is no pressure at the surface, the weight of a volume of air situated there would be in equilibrium with its elastic force, whereas it has been proved that the former is always an inconsiderable part of the latter.

(102.) But in the foregoing reasoning, says Mr. Ivory, a cause has been neglected which diminishes the elasticity of the air as we ascend above the Earth's surface, without affecting the force of Gravity in any degree. In the higher parts of the atmosphere a continually increasing degree of cold is found to prevail, the effect of which is to contract all bodies in their dimensions; and therefore, by the operation of this cause, as we ascend in the atmosphere, the expansive force of a given volume of air is constantly diminished and brought nearer to an equality with its weight. To estimate this effect with greater precision, let p', z', t', denote the Barometric pressure, the density, and the temperature by the centigrade Thermometer at the Earth's surface; and let the same letters, without the accent, denote corresponding elements at any height x; then if $\beta = \frac{3}{800}$, the expansion for one centigrade degree, the known laws that obtain in the expansion of elastic fluids will lead to this formula, *viz.*

$$\frac{p}{p'} = \frac{1+\beta t}{1+\beta t'} \times \frac{z}{z'}.$$

Now, here it may be remarked, that $\frac{p}{p'}$ is the measure of the elastic force at the height x in parts of the same force at the surface; and we see also that it depends on the temperature, as well as on the relative density $\frac{z}{z'}$. At the Earth's surface the quantity $\frac{1+\beta t}{1+\beta t'}$ is equal to unity, but continually diminishes as the temperature becomes less in ascending. We cannot conceive that it will become negative, nor can any bounds be set to its approach to zero. But when $\frac{1+\beta t}{1+\beta t'}$ is evanescent, or when $t = -266°$, the elastic force of the air will cease, and gravity will stop the further dilatation of the atmosphere. This reasoning, observes Mr. Ivory, is independent of the law of the densities; and it proves both that the atmosphere may be finite in its extent, and that it may have a finite density at its upper surface.

(103.) But it may be objected, that the effect of temperature on the air's elasticity has been verified only to a certain extent; and that in the case of air of a great rarity, and subjected to extreme degrees of cold, the law of dilatation and contraction may be very different from what it has been proved to be in the limited range of our experiments. This observation is probably well founded, but it will not destroy the force of what has been advanced. We know that air always gives out heat when it is compressed into a less volume, and absorbs heat when it expands. As long, therefore, as that fluid retains its elasticity, so long, we must conclude, will temperature continue to modify the changes of bulk which that force produces. The law of dilatation and contraction may, no doubt, undergo some change in different circumstances, but every expansion must be productive of cold, and every new degree of cold must diminish the elastic force of a given volume of air. Gravity continuing to act with nearly the same energy, while the elastic force of the air is continually diminished, these two forces will at length become equivalent, and will counterbalance one another, which is all that is necessary for imposing a limit to the extent of the atmosphere. We have proved, says Mr. Ivory, that air, if it were confined by the action of Gravity alone, would extend indefinitely into space; and it is not unreasonable to consider the effect of temperature as a contrivance for accurately attaching to the terrestrial globe a fluid so necessary in every point of view to the economy of nature.

(104.) Since it is found, continues Mr. Ivory, that all elastic fluids follow the same laws in regard to heat and pressure, the foregoing reasoning will be found equally true, whether we conceive the atmosphere as composed of one homogeneous fluid, or as a collection of many elastic gases and vapours, however much they may differ from one another in Specific Gravity.

His conjecture respecting the altitude of the Earth's atmosphere.

(105.) It may even be possible, adds Mr. Ivory, to form some reasonable conjecture as to the actual height of the finite atmosphere. Gay Lussac ascended in a balloon to the altitude of 3816 English fathoms, or nearly four miles and a quarter above the level of the Seine at Paris; the proportion of the heights of the Barometer in the balloon and at the surface of the Earth being 0.467 nearly, which is therefore the relative elasticity of the air. The temperatures, as observed at the extremities of the elevation, were 30°.8, and −9°.5 on the centigrade scale; and if we increase 0.467 to what it would have been, had the temperature remained unchanged during the ascent, we shall find 0.500 for the density of the air at the height ascended, in parts of the density at the surface of the Earth. Thus, in the decreasing scale of elasticities, the diminution is from 1 to 0.467; but in the decreasing scale of densities, it is only from 1 to 0.500.

The quantities of the one scale continually fall behind those of the other at a rate that must bring them to zero, whatever be the gradation of the latter. If we divide 3816 fathoms, the whole height ascended, by 40°.3 the difference of temperature, the elevation for depressing the Thermometer one degree will come out equal to 95 fathoms; and if we suppose that the same rate prevails in all parts of the atmosphere, the whole height will be 266×95 fathoms, or nearly 29 miles. The observations of the twilight show that this is less than the true altitude; and hence we must infer, that the Thermometer falls at a slower rate in the higher, than in the lower parts of the atmosphere. But, taking the observed rate of 95 fathoms for the first 40 degrees, and allowing, on an average, a double, or even a triple, elevation for the remaining 226°, we shall still find that the atmosphere will extend only to a moderate height above the Earth's surface.

Mr. Dalton's views respecting the finite extent of the atmosphere.

(106.) Mr. Dalton, in a Paper on the constitution of the atmosphere, published in the *Philosophical Transactions* for 1826, and before alluded to, has also referred to its finite extent. He commences his observations by referring to the 23d Proposition of the IId Book of the *Principia*, wherein Newton demonstrates, that if homogeneous particles of Matter were endued with a power of repulsion in the inverse ratio of their central distances, that, collectively, they would form an elastic fluid agreeing with atmospheric air in its mechanical properties. Newton does not, however, infer from this demonstration that elastic fluids must necessarily consist of such particles; and his argument requires that the repulsive power of each particle terminates, or very nearly so, in the adjacent particles.

(107.) From the Scholium to this Proposition, Newton was evidently aware of the difficulty of conceiving how the repulsive action of such particles could terminate so abruptly as his supposition demands; but in order to show that such cases exist in nature, he finds a parallel one in Magnetism.

Principle on which he founds a limit to the atmosphere.

(108.) Following up his reasoning Mr. Dalton observes, that on the hypothesis of the density of any atmosphere diminishing in Geometrical progression to intervals of ascent in Arithmetical progression, every atmosphere must be unlimited, or of infinite extent. But if an atmosphere is constituted of particles on the Newtonian hypothesis, *it must have a limit; and which limit will exist where the repulsion of two particles becomes equal to the weight of one of them.*

Comparison of the relative heights of two atmospheres.

(109.) We have no data, continues Mr. Dalton, from which to determine the *absolute* height above the surface of the Earth to which any one atmosphere can ascend; but we can form a pretty accurate comparison of the *relative* heights to which two atmospheres would ascend, especially if the relative weights of their atoms be known.

(110.) For instance, says he, we know that the diameter of an elastic particle of carbonic acid is nearly, or exactly, the same as that of a particle of hydrogen under the same pressure; also that their weights are as 20 to 1. At two miles' elevation, the elasticity of an atmosphere of carbonic acid gas is diminished one half; and at 40 miles' elevation, that of hydrogen is diminished one half. Now let it be supposed that at 30 miles' elevation the carbonic acid atmosphere ceases to exist, or terminates, at which elevation its elasticity must be, according to the Geometrical progression, nearly $\frac{1}{33000}$; then, by the same law, the elasticity of the hydrogen atmosphere must be $\frac{1}{33000}$ at the height of $15 \times 40 = 600$ miles; also the diameters of the particles of the two gases are still equal at those elevations, because they vary as the cube roots of the elasticities inversely; that is, if the diameters of the particles of carbonic acid and hydrogen at the surface of the Earth be denoted by 1, that of carbonic acid at 30 miles will be represented by $\sqrt[3]{33000}$, and that of hydrogen at 600 miles' elevation will also be $\sqrt[3]{33000}$. But by the hypothesis, this distance is capable of supporting a weight as 20, (namely, the weight of one atom of carbonic acid;) the hydrogen atmosphere, therefore, must be further elevated, till it is capable of supporting a weight only as 1, (namely, the weight of an atom of hydrogen;) this will take place when the elasticity is still further diminished in the ratio of 20^3 to 1^3, or 8000 to 1. Hence, we shall have to extend the atmosphere about $13 \times 40 = 520$ miles further before it can terminate, or the height of 1120 miles. In this estimate we have not taken into consideration the variable force of Gravity. At the height of 1400 miles the force of Gravity is reduced one half, nearly; on this account the elevation of the hydrogen atmosphere will be increased between one and two hundred miles more, so as to make it amount to twelve or thirteen hundred miles. The variation of temperature in ascending does not materially affect Mr. Dalton's views.

(111.) Thus it appears, that, upon the assumption made by the Manchester Philosopher, the hydrogen atmosphere must be 40 times the altitude of the carbonic acid atmosphere. If he had assumed the utmost height of the carbonic acid atmosphere less than 30 miles, the disproportion of the two heights would have been still greater; and if more than 30 miles, it would have been less; but, in this case, the absolute difference would be greater.

(112.) By applying these principles to the terrestrial atmosphere, composed as it is of azote, oxygen, carbonic acid, and aqueous vapour, and fixing the limit of altitude in a full atmosphere (of 30 inches of mercury) of oxygen gas at 45 miles, Mr. Dalton finds that of an atmosphere of the same gas of 6.3 inches of mercury will be found to be about 38 miles, the atom of oxygen being 7; and that of azotic gas of 23.7 inches weight will be found 54 miles, if the atom of azote be taken as 5; but if the atom of azote be double this weight, as is supposed by many, but Mr. Dalton thinks without sufficient reason, then the height of the azotic atmosphere will be only 44 miles. The very fine and attenuated carbonic acid atmosphere must ascend to the height of 10 miles, if a full atmosphere of this gas ascend to 30 miles; and that of aqueous vapour to the height of 50 miles, allowing the Specific Gravity of steam to be .625, and the weight of its atom 8.

Views of Mr. Luke Howard.

(113.) Mr. Luke Howard, in alluding to this interesting subject, remarks, that the surface of the atmosphere is less elevated, and better defined, than many imagine. A portion of air, says he, rarefied by means of the air-pump, does indeed exhibit an elasticity, which seems limited only by the imperfection of the instrument. For the most minute residuum still appears to fill the vessel, and to press against it in all directions. But this is done at a temperature which, compared with that of the extreme boundaries of the atmosphere, is probably that of the steam in a high-pressure engine to the water in a well. We know that, in ascending into the atmosphere, the temperature is found to decrease with the decreasing density of the air; and even under a vertical Sun, between the Tropics, a line of perpetual snow on the mountains indicates a boundary within our reach, which the heat never has ascended in mass to penetrate. There is consequently no source from whence air, conveyed to the summit of the atmosphere, could obtain heat necessary to such extreme rarefaction; the whole sensible heat of the atmosphere being derived originally from the Earth's surface, and distributed in an inverse proportion to the elevation. At an elevation, therefore, not perhaps on a mean more than ten times that of the highest mountains, or fifty miles at the Equator, and considerably less at the Poles, there exists a perpetual zero of temperature, and with it an effectual limit to the further expansion of the atmosphere. Here, the spheroidal body of gases, enveloping our globe, has probably a well-defined surface, (its extent considered,) where the air, though greatly attenuated, is much less rare than we can make it in the receiver of an air-pump; in a word, a fluid, capable of rising and falling, like the waters of the Ocean, by alterations of Gravity.

On the Distribution of Temperature on the Surface of the Earth. Isothermal Lines, &c.

Distribution of heat over the surface of the globe.

(114.) The distribution of heat over the surface of the globe, says Humboldt, belongs to that class of phenomena of which the general principles have long been known, but which were incapable of being submitted to an exact calculation, till experiment and observation had furnished the data from which the theory might obtain the corrections of the different elements it requires.

Connected with the most interesting inquiries.

(115.) An investigation of the temperature of the surface of the globe is a problem connected with the most interesting inquiries. It involves in its consideration the conditions of the arid plains of a tropical climate, where the various orders of vegetable beings are so powerfully influenced by a vertical Sun; or passing from these into the luxuriant regions of the olive and the vine, and to the milder and more uniform temperature of Italy and Spain; and thence again to the variable climates, and the more verdant Kingdoms of the North, until at length we arrive at the region of blighted vegetation, where nothing can exist but the birch and the pine, and the chain of vegetable existence is at last terminated in the hoary desolation of the Arctic Zone.

(116.) Amidst this great circle of Physical changes, the Philosopher looks for materials on which to rear the beautiful theories of his creation; though it is much to be feared, that theoretical considerations have too often usurped the place of the laborious and less inviting task of experimental observation.

(117.) It is a remarkable circumstance in the history of this interesting problem, that Philosophers have been accustomed to consider the distribution of heat in a particular region, as the type of the laws which govern the whole globe; and, in place of estimating the distribution of heat in its general relations to continents and seas, it has been usual to consider as exceptions, every thing which differed from the adopted type; or, by pursuing a method still more dangerous in investigating the laws of Nature, to take the mean temperatures for every five degrees of latitude, and confounding together places under different meridians.

The distribution of heat depends on many causes.

(118.) The distribution of heat depends by its nature on many diversified causes. The Sun may exert its influence on a single point, but that influence will be immediately modified by the influence of local circumstances, and hence the distinction that has for a long time been made between the *solar* and the *real climate* of a place. It will be sufficient to mention, in order to render this distinction evident, how much the temperatures of different latitudes are influenced by the mixture of different winds; the vicinity of seas which are immense reservoirs of an almost invariable temperature; the unequal and varied surface, the Chemical nature, the colour, the radiating power, and the rate of evaporation from the soil; the direction of the chains of mountains, which act either in favouring the play of descending currents, or in affording shelter against particular winds; the shapes of different Countries, their mass and prolongation towards the Poles; the quantity of snow which covers them in winter, their temperature, and their reflection in summer; and, finally, the fields of ice, which form, as it were, circumpolar continents, variable in their extent, and whose detached parts, dragged away by currents, modify in a sensible manner the climate of the temperate zone. These modifying causes will be sufficient to show, that a great and necessary distinction exists between the solar and real climate of a place. We must not, however, forget, that the local and multiplied causes which modify the action of the Sun upon a single point of the globe, are themselves but *secondary* causes, the effects of the motion which the Sun produces in the atmosphere, and which are propagated to great distances.

Halley's theory.

(119.) It is from theory alone that we must expect to determine the distribution of heat over the surface of the globe, so far as it depends on the immediate and instantaneous action of the Sun. In the year 1693, previous to the use of comparable Thermometers, and to precise ideas of the mean temperature of a place, Halley laid the first foundations of a theory of the heating action of the Sun under different latitudes.* He proved that these actions might compensate for the effect of the obliquity of the rays. The ratios which he points out do not, however, express the mean heat of the Seasons, but the heat of a summer-day at the Equator and under the Polar Circles, which he finds to be as 1.834 to 2.310, or as 100 to 127.

Mairan's theory.

(120.) In two Memoirs,† Mairan attempted to solve the problem of the solar action, by treating it in a much more extended and general manner, and for the first time compared the results of theory with those of observation; and as he found the difference between the heat of summer and winter much less than it ought to be by calculation, he recognised the permanent heat of the globe and the effects of radiation. Without mistrusting the observations he employed, he conceived the strange theory of central emanations, which increase the heat of the atmosphere from the Equator to

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* *Phil. Trans.* for 1693.

† *Mém. de l'Acad.* 1719 and 1765.

the Pole. He supposed these emanations to decrease to the parallel of 74°, where the solar summers attain their maximum, and that they then increase from that latitude to the Pole.

Euler's theory.

(121.) Euler was not more successful than Mairan in his theoretical Essays on the solar heat. He supposed the negative sines of the Sun's altitude during the night to give the measure of the nocturnal cooling, and obtained the extraordinary result,[*] that, under the Equator, the cold at midnight ought to be more rigorous than during winter under the Poles. Fortunately this transcendant analyst attached but little importance to the result, and to the theory from which it was deduced.

Investigations of Lambert.

(122.) Lambert,[†] dissatisfied with the route followed by his predecessors, directed his attention to two very different objects. He investigated analytical expressions for the curves which express the variation of temperature in a place where it had been observed, and resumed in its greatest generality the theorem of the solar action. He gave formulæ, from which he found the heat of any day at all latitudes; but being perplexed with the determination of the nocturnal dispersion of the acquired heat, or the subtangents of the nocturnal cooling, he gave tables of the distribution of heat under different parallels, and in different Seasons, which differ, however, so widely from observation, that it would be difficult to ascribe their deviations to the radiating power of the Earth, or to the influence of disturbing causes.

Of Mayer.

(123.) In 1755, Mayer, the celebrated reformer of the Lunar Tables, published an Essay[‡] essentially differing from those we have quoted, and in which the learned author attempted to deduce the mean heat empirically, by the application of coefficients furnished by observation. We shall hereafter allude more particularly to this interesting performance, when we come to treat of the formulæ of temperature.

Of Kirwan

(124.) Kirwan, in his Work on Climates, and in a learned Meteorological Memoir, contained in the VIIIth volume of the *Memoirs of the Royal Irish Academy*, attempted at first to follow the method pursued by Mayer; but richer in observations than his predecessors, he soon perceived that, after long calcutions, his results agreed ill with observation.[§] In order to try a new method, he selected, in the vast extent of sea, those places whose temperature suffered no change but from permanent causes. These were in that part of the Pacific Ocean comprised between the parallels 45° North and 40° South latitude, and that portion of the Atlantic Ocean, contained between the parallels of 45° and 80°, from the coasts of England to the Gulf Stream. Kirwan also endeavoured to determine, for every month, the mean temperature of these seas in different latitudes; and these results afforded him terms of comparison with the mean temperatures observed on the solid part of the terrestrial globe. But it is easy to conceive, says Humboldt, that this method has no other object, but to distinguish in climates, that is in the total effect of *calorific influences*, that which is due to the immediate action of the Sun on a single point of the globe. Kirwan first considered the Earth as uniformly covered with a thick stratum of water, and then compares the temperatures of this water at different latitudes, with observations at the surface of continents identified with mountains, and unequally prolonged towards the Poles.

(125.) This interesting investigation may enable us, says Humboldt, to appreciate the influence of local causes, and the effect which arises from the position of seas, on account of the unequal capacity of water and Earth for absorbing heat. It is even better fitted for this object, than the method of means deduced from a great number of observations made under different meridians; but in the actual state of Physical knowledge, the method proposed by Kirwan cannot be followed. A small number of observations made far from the coasts, in the course of a month, fixes, without doubt, the mean annual temperature of the sea at its surface; and, on account of the slowness with which a great mass of water follows the changes of the temperature of the surrounding air, the extent of variations in the course of a month is smaller in the Ocean than in the atmosphere. But it is still greatly to be desired,[*] that we should be able to indicate by direct experience, for every parallel and for every month, the mean temperature of the Ocean under the temperate zone.

Of Cotte. Of Humboldt.

(126.) Kirwan was succeeded by many ingenious and interesting writers, among whom may be mentioned the useful and laborious compiler Cotte; but it is to the enlightened and enterprising traveller Humboldt, that we owe our comparatively enlarged notions of the distribution of terrestrial heat. In his Memoir on Isothermal Lines, published in the *Mémoires d'Arcueil*, tom. iii.,[†] he has entered with the utmost generality on the consideration of all the circumstances connected with this interesting inquiry; and in the excellent translation given of it by Brewster, in the early volumes of the *Edinburgh Philosophical Journal*,[‡] that Philosopher justly remarks, "that it must be constantly referred to in all subsequent speculations on Meteorology, and should be familiar to every person who pursues this important study."

His Isothermal lines.

(127.) Humboldt was led to the consideration of this highly interesting subject, by visiting the most elevated plains of the New Continent, and tracing the different vicissitudes of climate existing in the mighty chain of the Cordilleras. To connect the system of climates of the Old World with those of the New, this accomplished traveller endeavoured to find at every 10° of latitude, under different meridians, a small number of places whose mean temperature had been correctly ascertained, and through these, as so many standard points, he supposed his *isothermal lines*, or lines of *equal heat, to pass*. These lines were traced upon a map, in a manner analogous to the ordinary Magnetic lines of dip and variation, and their properties contemplated in

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[*] *Comment. Petrop.* tom. ii.

[†] *Pyrometrie oder Vom Muase des Feuers*, 1779.

[‡] *De Variationibus Thermometri accuratius definiendis.* (*Opera Inedita*, vol. i.)

[§] Kirwan's *Estimate of the Temperature of the Globe*, ch. iii.

[*] Humboldt, *Rélation Historique*, tom. i.

[†] The interesting Papers contained in the *Mémoires d'Arcueil*, owe their origin to a Society of distinguished men, who assembled once a fortnight, at the elegant retreat of the elder Berthollet, in the little village of Arcueil near Paris. The day was spent in perusing the latest Scientific publications, reading and discussing Philosophical papers, projecting new experiments, and in other Philosophical occupations. Besides La Place, who appeared rather as a patron and counsellor, the members consisted of Humboldt, Decandolle, Biot, Gay Lussac, Malus, Thenard, the younger Berthollet, and Collet-Descostils.

[‡] *Edinb. Philosophical Journal*, vols. iii., iv., and v.

a twofold point of view; first with relation to the same *horizontal* plane on the surface of the Earth; and, secondly, as rising on the declivities of mountains in a *vertical* plane, embracing in this comprehensive view, the three rectangular coordinates of latitude, longitude, and elevation above the sea.

Choice of Meteorological positions to enable him to determine the isothermal lines.

(128.) In tracing the courses of these magnificent lines through the different regions of the Earth, the choice of Meteorological positions, and the character of the observations made at them, became of the highest importance. No observations could be adopted, but such as had been spread over a wide surface of time, measured by instruments constructed with Philosophic accuracy, and registered with fidelity and care. Many good observations were rejected, says Humboldt, solely because the absolute height of the place of observation was unknown. This was the case with the observations made in Asia Minor, in Armenia and Persia, and with the greater part of Asia; and at the time that Humboldt wrote, the phenomenon, for such it may with the most perfect truth be called, was presented, of 500 well-determined points in the Equinoctial regions of the New World, the greater number of which were simple villages and hamlets of recent growth, containing only the germs of civilization, whereas the heights of Erzerum, of Bagdad and Aleppo, of Teheran, Ispahan, Delhi, and Lassa, places whose names have been known from a remote antiquity, and associated in our recollections with all the charms of Oriental Poetry and Romance, have their levels above the surrounding seas, and their temperatures at this moment undetermined.

(129.) In another part of our Paper we shall discuss the admirable precautions adopted by Humboldt in taking his averages of temperature, and also in reducing his different temperatures to general expressions. We now proceed at once to trace the course of the *Isothermal lines* on the surface of the globe, and at the level of the sea.

Temperatures not the same under the same parallels.

(130.) A slight attention to the difference of climates, at once reveals that the temperatures are not the same under the same parallels; and that advancing 70° to the East or West, a sensible alteration in the heat of the atmosphere is found. Places situated, however, under the same latitudes do not differ in America and Europe by so many degrees of temperature, as has been commonly supposed.

TABLE XVI.

		Latitude.	Mean Temperature.
I. Parallels of Georgia, of the State of Mississippi, of Lower Egypt, and Madeira.	Natches	31° 28′	64° 8′
	Funchal	32 37	68 7
	Orotava	28 25	69 8
	Rome	41 53	60 4
	Algiers	36 48	70 0
	Difference	7 0	4 1
II. Parallels of Virginia, Kentucky, Spain, and the South of Greece.	Williamsburg	38° 8′	58° 0′
	Bourdeaux	44 50	56 5
	Montpellier	43 36	59 4
	Rome	41 53	60 4
	Algiers	36 48	70 0
	Difference	7 0	7 7
III. Parallels of Pennsylvania, Jersey, Connecticut, Latium, and Romelia.	Philadelphia	39° 56′	54° 9′
	New York	40 40	53 8
	St. Malo	48 39	54 5
	Nantes	47 13	54 7
	Naples	40 50	63 3
	Difference	7 0	9 5.
	Ipswich	42° 38′	50° 0
	Cambridge, (Amer.)	42 25	50 4
	Vienna	48 13	50 5
	Manheim	49 29	51 3
	Toulon	43 7	62 1
	Rome	41 53	60 4
	Difference	6 30	11 0
IV. Parallels of Canada, Nova Scotia, France, and the South of Germany.	Quebec	46° 47′	41° 9′
	Upsal	49 51	41 9
	Padua	45 24	57 7
	Paris	48 50	51 4
	Difference	13 0	12 6
V. Parallels of Labrador, the South of Sweden, and Courland.	Nains	57° 0′	26° 4′
	Okak	57 20	29 8
	Umea	63 50	33 3
	Enontekies	68 30	27 0
	Edinburgh	55 58	47 8
	Stockholm	59 20	42 3
	Difference	11 0	17 1

Remarks on the foregoing Table.

(131.) This Table[*] indicates the difference of climates, expressed by that of mean temperature, and by the number of degrees which it is necessary to go Northward in Europe, in order to find the same quantity of annual heat as in America; and the differences under the column of latitudes, are the differences between the latitude of a place in Europe and a place in America, which have the same mean temperature; and the differences under the column of mean temperatures, are the differences between the mean temperatures of a place in Europe and of one in America, having the same latitude. As a place could not be found in the Old World, whose mean temperature was 48°, the same as that of Williamsburg, Humboldt supplied it with an interpolation between the latitudes of two points, whose mean temperatures are 56°.5, and 59°.4. By an analogous method, and by employing only good observations, he found also:

Position of the Isothermal line of 32°.

1°. *That the Isothermal line of* 32° *passes between Uleo and Enontekies in Lapland, (latitude* 66° *to* 68°, *East longitude, from London,* 19° *to* 22°,) *and Table Bay in Labrador, (latitude* 54°, *West longitude* 58°.)

Of 41°.

2°. *The Isothermal line of* 41° *passes by Stockholm (latitude* 60°, *East longitude* 18°) *and the Bay of St. George in Newfoundland, (latitude* 48°, *and longitude* 59°.)

Of 50°.

3°. *The Isothermal line of* 50° *passes by Belgium (latitude* 51°, *East longitude* 2°) *and near Boston, (latitude* 42° 30′, *West longitude* 70° 59′.)

Of 59°.

4°. *The Isothermal line of* 59° *passes between Rome and Florence, (latitude* 43° 0′, *East longitude* 11° 40′,) *and near Raleigh in North Carolina, (latitude* 36° 0′, *and West longitude* 76° 30′.)

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[*] See Humboldt's *Prolegomena de distributione geographicâ plantarum, secundum cœli temperiem et altitudinem montium*, p. 68.

The differences afforded by these lines of equal heat.

(132.) The direction of these lines of equal heat, gives for the two systems of temperature known by precise observations, *viz.* part of the middle and West of Europe and that of the coast of America, the following differences:

TABLE XVII.

Latitude.	Mean Temperature of the West of the Old World.	Mean Temperature of the East of the New World.	Difference.
30°	70°.52	66°.92	3°.60
40	63.14	54.50	8.64
50	50.90	37.94	12.96
60	40.64	23.72	16.92

Isothermal lines approach each other towards the South, and converge towards the North.

(133.) In tracing the directions of the Isothermal lines from Europe to the Atlantic Provinces of the New World, they are found to approach each other from parallelism towards the South, and to converge towards the North, particularly between the Thermometric curves of 41° and 50°. In pursuing these lines to the West, the Thermometric means prove that they do not again rise, the quantity of heat which each point of the globe receives under the same parallels being nearly the same on the East and West sides of the Alleghany range.[*] The presence of the *Gleditsia Monosperma*, the *Catalpa*, the *Aristolochia Sypho*, and other vegetable productions several degrees further to the North, in the basin of the Ohio, than on the coast of the Atlantic,[†] led at one time to the supposition, that there was a difference of temperature amounting to three degrees; but Humboldt has now clearly explained, that the migration of vegetables towards the North are favoured in the basin of the Mississippi, by the form and direction of the valley which opens from the North to the South; whereas in the Atlantic Provinces, the valleys are transverse, and oppose great obstacles to the passage of plants from one valley to another.

Other remarks relating to the parallelism of Isothermal lines.

(134.) If the Isothermal lines remain parallel, or nearly so, to the Equator, from the Atlantic shores of the New World to the East of the Mississippi and the Missouri, it cannot be doubted that they rise again beyond the Rocky Mountains, on the opposite coast of Asia, between 35° and 55° of latitude. In New California, the olive is cultivated with success along the Canal of Santa Barbara, and the vine from Monterey to the North of the parallel of 37°, which is that of the Chesapeake Bay. At Nootka, in the Island of Quadra and Vancouver, and almost in the latitude of Labrador, the smallest rivers do not freeze before the month of January. Through 122° 40′ of West longitude, the Isothermal line of 50° of temperature appears to pass almost as in the Atlantic part of the Old World, at 50° of latitude. The Western coasts of the two worlds resemble one another to a certain point.[*] But these returns of the Isothermal lines do not extend beyond 60°. The curve of 32° is already found to the South of the Slave Lake, and it comes still further South in approacing Lakes Superior and Ontario.

The nodes of the Isothermal lin of 55°.4 known round the whole globe.

(135.) In advancing from Europe towards the East, the Isothermal lines again descend,[†] but the number of fixed points are few. The few good materials which Humboldt possesses, have enabled him, however, to trace the curves of 32° and 55°.4; and the nodes of the latter curve are known round the whole globe. It passes to the North of Bourdeaux, (latitude 45° 46′ North, longitude 0° 37′ West,) near Pekin (latitude 39° 54′ North, longitude 116° 27′ East) and Cape Foulweather to the South of the embouchure of the Colombia, (latitude 44° 40′ North, and longitude 104° West,) its nodes being distant at least 162° of longitude.

The Isothe mal line of 32° bears a remarkable analogy to the Magnetic Equator.

(136.) It is worthy of observation, that the position of the Isothermal line of 32° bears a remarkable analogy to the Magnetic Equator, whose singular inflexions in the South Sea create so many diversities in the inclination of the needle. The direction and the inflexions of the curve of 32° influence the neighbouring Isothermal lines, and we may even believe, continues Humboldt, that, in the distribution of climates, the line of 32° determines the curve of greatest heat, creating as it were an *Isothermal Equator*, and that in America and Asia, through 78° of West and 102° of East longitude, the Torrid Zone commences more to the South of the Tropic of Cancer, or that it there presents temperatures of less intensity. An attentive examination of the phenomena, however, proves that this is not the case. Whenever we approach the Torrid Zone below the parallel of 30°, the Isothermal lines become more and more parallel to one another and to the Earth's Equator; and hence Humboldt infers, that the great colds of Canada and Siberia do not extend their action to the Equatorial plains.[‡]

Isothermal Equator.

Partial inflections c Isothermal lines.

(137.) There are partial inflexions of the Isothermal lines, forming systems by themselves, modified by particular local causes. An example of the kind is presented in the strange inflexions of the Thermometric curves on the shores of the Mediterranean, between

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[*] The following comparison of the mean temperatures has been deduced with great care.

CINCINNATI.		PHILADELPHIA.	
Lat. 36° 6′ N., Long. 84° 24′ W.		Lat. 39° 56′ N., Long. 75° 16′ W.	
Winter	32°.9	Winter	32°.2
Spring	54.1	Spring	51.4
Summer	72.9	Summer	73.9
Autumn	54.9	Autumn	56.5
Mean	53.7	Mean	53.5

[†] Humboldt, *Essai sur la Géographie des Plantes*, p. 154.

[*] On account of the influence of West and South-West winds. See Dalton's *Meteorological Observations*, p. 125.

[†] In comparing places from West to East, and nearly under the same parallel, we find:

WEST.	Lat.	Mean Temp.	EAST.	Lat.	Mean Temp.
St. Malo	48° 39′	54°.5	Vienna	48° 13′	50°.5
Amsterdam	52 21	53.4	Warsaw	52 14	48.6
Naples	40 50	63.3	Pekin	39 54	54.9
Copenhagen	55 41	45.7	Moscow	55 46	40.1
Upsal	59 52	41.9	Petersburgh	59 56	38.8

The elevation of Pekin is inconsiderable. That of Moscow is 984 feet. The absolute temperature of Madrid, to the West of Naples, is 59°; but the city is elevated 1978 feet above the level of the sea.

[‡] If we have long regarded the Old World, says Humboldt, as warmer between the Tropics than the New World, it is first because, till 1760, travellers used Thermometers of spirits of wine, coloured, and affected by light; secondly, because they observed them either under the reflection of a wall, or too near the ground, and when the atmosphere was filled with sand; and thirdly, because, in place of calculating the true *mean*, they used only the Thermometric maximum and minimum.

Marseilles, Genoa, Lucca, and Rome,* and those which determine the difference between the climate of the Western coast and the interior of France. The causes of these aberrations depend much less on the quantity of heat received by a part of the globe during the whole year, than upon the unequal distribution of heat between winter and summer.

Distribution of heat in Isothermal lines.

(138.) The distribution of heat over different parts of the year, differs in the same Isothermal line. This is remarkably exemplified in the succeeding Table :

Table XVIII.—*Differences of the Seasons from the Equator to the Polar Circle.*

Isothermal lines of	Cisatlantic Region. Long. 1° W. and 17° E.			Transatlantic Region. Long. 58°——72° W.		
	Mean Temperature.			Mean Temperature.		
	Winter.	Summer.	Diff.	Winter.	Summer.	Diff.
68°	59°.0	80°.6	21°.6	53°.6	80°.6	27°.0
59	44.6	73.4	28.8	39.2	78.8	39.6
50	35.6	68.0	32.4	30.2	71.6	41.4
41	24.8	60.8	36.0	14.0	66.2	52.2
32	14.0	53.6	39.6	1.4	55.4	54.0

(139.) This Table shows the increase of the difference between the winters and summers from 28° and 30° to the parallels of 55° and 65°. This increase is more rapid in the transatlantic zone, where the Isothermal lines of 32° and 50° approach one another very much; but it is remarkable, that, in the two zones which form the two systems of different climates, the division of the annual temperature between winter and summer is made in such a manner, that upon the Isothermal line of 32°, the difference of the two seasons is almost double that which is observed on the Isothermal line of 68°.

(140.) There are also some differences worthy of examination between the winters and summers, in following the same Isothermal line from West to East. The differences between the seasons of the year are less near the convex summits of the Isothermal curves, where these curves rise again towards the North Pole, than near the concave summits. The same causes which affect the inflection, or the greatest curvature of the Isothermal lines, tend also to equalize the temperatures of the seasons.

(141.) The whole of Europe, says Humboldt, compared with the Eastern parts of America and Asia, has an insular climate, and, upon the same Isothermal line, the summers become warmer and the winters colder, as we advance from the meridian of Mont Blanc towards the East or West. Europe may be considered as the Western prolongation of the Old Continent; and the Western parts of all continents are not only warmer at equal latitudes than the Eastern parts, but even in the zones of equal annual temperature, the winters are more rigorous, and the summers hotter on the Eastern coasts than upon the Western coasts of the two continents. The Northern part of China, like the Atlantic region of the United States, exhibits seasons strongly contrasted,* while the coasts of New California, and the embouchure of the Colombia, have winters and summers almost equally temperate. The Meteorological constitution of these countries in the North-West, resembles that of Europe as far as 50° or 52° of latitude. In comparing the two systems of climates, the concave and convex summits of the same Isothermal lines, we find at *New York*, the summer of *Rome* and the winter of *Copenhagen ;* at *Quebec*, the summer of *Paris* and the winter of *Petersburgh*. At *Pekin*, also, where the mean temperature of the year is that of the coasts of *Brittany*, the scorching heats of summer are greater than at *Cairo*, and the winters as rigorous as at *Upsal*.

Mean temperature of the year on the same Isothermal line.

(142.) The mean temperature of the year being equal to the fourth part of the winter, spring, summer, and autumnal temperatures, we shall have upon the same Isothermal line of 53°.6,

At the *concave* summit in America, 74° 40′ W. long. $$53^\circ.6=\frac{32^\circ+52^\circ.3+75^\circ.6+54.^\circ5}{4}.$$

At the *convex* summit in Europe, 2° 20′ West long. $$53^\circ.6=\frac{40^\circ.1+51^\circ.8+68^\circ.4+54^\circ.1}{4}.$$

At the *concave* summit in Asia, 116° 20′ East long. $$53^\circ.6=\frac{-24^\circ.8+54^\circ.7+80^\circ.6+54^\circ.3}{4}.$$

Analogy between the Eastern coasts of Asia and America.

(143.) This analogy between the Eastern coasts of Asia and America sufficiently proves, says Humboldt, that the inequalities of the seasons depend on the prolongation and enlargement of continents towards the Pole; of the size of seas in relation to their coasts; and on the frequency of the North-West winds, which are the *Vents de Remous* of the Temperate Zone, and not on the proximity of some plateau or elevation of the adjacent lands. The great plateaus of Asia do not stretch beyond 52° of latitude; and, in the interior of the New Continent, all the immense basin bounded by the Alleghany range, and the rocky mountains, and covered with secondary formations, is not more than from 656 to 920 feet above the level of the Ocean, according to the levels taken in Kentucky, on the banks of the Monongahela, at Lake Erie.

(144.) The following Table indicates, for all the habitable parts of the Temperate Zone, the division of the same quantity of annual heat between the seasons of summer and winter. The numbers which it contains, says Humboldt, are either the result of direct observations, or of interpolations between a great number of observations made in neighbouring places, and situated under the same meridian. Humboldt traced each Isothermal curve from West to East, giving the preference to places situated near the summits of the curve, as presenting at the same time the greatest differences in the distribution of the annual heat. The longitudes are reckoned from the Observatory at Greenwich.

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	Lat.	Mean Temp.		Lat.	Mean Temp.
Bologna....	44° 29′	56°.3	Marseilles	43° 17′	58°.8
Genoa......	44 25	66.6	Rome........	41 53	60.4

* Buffon distinguishes places which exhibit great difference in their warmest and coldest months, by the name of *Excessive Climates*.

TABLE XIX.—*Isothermal Lines from 32° to 68°.*

	Longitude.	Latitude.		Mean Temperature.	
				Winter.	Summer.
Isoth. line of 68°.	82° 10′ W.	29° 30′	Florida	53°.6	80°.6
	16 56 W.	32 37	Madeira	63.5	72.0
	3 0 E.	36 48	North Africa	59.0	80.6
Isoth. line of 63°.5.	89 40 W.	32 30	Mississippi	46.4	77.0
	14 11 E.	40 50	Italy	50.0	77.0
Isoth. line of 59°.	84 10 W.	35 30	Basin of the Ohio	39.2	77.9
	3°–4° E.	43 30	Middle of France	44.6	75.2
Isoth. line of 54°.5.	84 40 W.	38 30	America, West of Allegh	34.7	75.2
	74 10 W.	40 0	America, East of Ditto	32.5	77.0
	1 32 W.	47 10	West of France	39.0	68.0
	9 20 E.	45 30	Lombardy	34.7	73.4
	116 20 E.	40 0	East of Asia	26.6	82.4
Isoth. line of 50°.	84 20 W.	41 20	America, West of Allegh	31.1	71.6
	71 10 W.	42 30	America, East of Ditto	30.2	73.4
	6 40 W.	52 30	Ireland	39.2	59.5
	0 40 W.	53 30	England	37.4	62.6
	2 20 E.	51 0	Belgium	36.5	63.5
	19 0 E.	47 30	Hungary	31.1	69.8
	116 20 E.	40 0	Eastern Asia	23.0	78.8
Isoth. line of 45°.5.	71 0 W.	44 42	America, East of Allegh	23.9	71.6
	2 10 W.	57 0	Scotland	36.1	56.5
	12 35 E.	55 40	Denmark	30.3	62.6
	21 20 E.	53 5	Poland	28.0	66.2
Isoth. line of 41°.	71 10 W.	47 0	Canada	14.0	68.0
	9 20 E.	62 45	West of Norway	24.8	62.6
	17 20 E.	60 30	Sweden	24.8	60.8
	24 20 E.	60 0	Finland	23.0	63.5
	36 20 E.	58 30	Central Russia	22.1	68.0
Isoth. line of 36°.5.	71 40 W.	50 0	Canada	6.8	60.8
	18 5 E.	62 30	West coast of Gulf of Bothnia	17.6	57.2
	22 20 E.	62 50	East coast of Ditto	16.5	59.0
Isoth. line of 32°.	57 40 E.	53 0	Labrador	3.2	51.8
	19 50 E.	65 0	Sweden	11.3	53.6
	25 20 E.	71 0	North extremity of Norway	23.9	43.7

Determinate type for the division of Heat.

(145.) It is impossible to examine the preceding Table without observing, that the division of the annual heat between summer and winter follows, on each Isothermal line, a determinate type; that the deviations of that type are contained between certain limits, and that they obey the same law in the zones which pass by the concave or convex summits of the Isothermal lines: for example, by 58°—68° of West longitude, and 116° of East longitude.

(146.) The following Table shows the oscillation, or the *maxima* and *minima*, observed in the division of the heat between the seasons. Humboldt has also added to it the means of the winters and summers found at different degrees of longitude, and under the same Isothermal line.

TABLE XX.

Isothermal Lines.	Degrees of Longitude examined.	Oscillations observed in the Means.		Means calculated.	
		Winters.	Summers.	Winters.	Summers.
32°	83	3°.2 to 24°.8	51°.8 to 53°.6	14°.0	52°.7
41	107	14.0 24.8	62.6 68.0	19.4	65.3
50	200	23.0 37.4	62.6 78.8	30.2	70.7
59	87	39.0 44.6	75.2 77.0	41.9	75.2
68	84	53.6 59.0	71.6 80.6	56.3	77.9

Isocheimal lines.

(147.) If we endeavour to discover on *different* Isothermal lines, points at which equal degrees of *winter* temperature prevail, a new system of lines will be created, which have been denominated *Isocheimal lines*. In Europe, it has been found that these *Isocheimal lines* cut systems of *Isothermal lines* which are 9° distant; and hence it is that the Isocheimal lines deviate much more than the Isothermal lines from the terrestrial parallels. The latitudes of two places that have the same annual temperature cannot differ more than from 4° to 5°, while two places, whose mean winter temperature is the same, may differ more than 9° or 10° of latitude. The further we advance to the East, the more rapidly these differences increase.

Isotheral lines.

(148.) If, again, we connect on *different* Isothermal lines, points at which equal degrees of *summer* temperature prevail, another system of lines will arise, which have been denominated *Isotheral lines*. These *Isotheral lines* are found to follow a direction exactly contrary to the *Isocheimal lines*. The same summer temperature prevails at Moscow, in the centre of Russia, as towards the mouth of the Loire, notwithstanding a difference of 11° of latitude,—the effect of the Earth's radiation on a vast continent deprived of mountains.

Temperature as it affects vegetable produce.

(149.) It would be interesting to our readers, and to ourselves, did our limits permit, to follow Humboldt through the whole of his inquiries respecting the connection of the Isothermal lines with the varied productions of the vegetable world; to trace the temperatures necessary for the coffee-tree, the olive, and the vine, or the different conditions of the atmosphere which the varieties of grain require. We may, however, remark, that the olive is cultivated in our continent between the parallels of 36° and 44°, wherever the annual temperature is from 62°.6 to 58°.1, and where the mean temperature of the coldest month is not below 41°.0 or 42°.8, and that of the whole summer 71°.6 or 73°.4. The region of potable wines extends in Europe between the Isothermal lines of 62°.6 and 50°, which correspond to the latitudes of 36° and 48°. The cultivation of the vine extends, though with less advantage, even to countries whose annual temperature descends to 48°.2 and 47°.48; that of winter to 33°.8, and that of summer to 66°.2 and 68°. These Meteorological conditions are fulfilled in Europe as far as the parallel of 50°, and a little beyond it. In America, they do not exist further North than 40°. On the continent of Western Europe, the winters, whose mean temperature is 32°, do not commence till on the Isothermal lines of 48°.2 and 50°, in from 51° to 52° of latitude; while in America, we find them already on the Isothermal lines of from 51°.8 to 53°.6, under from 40° to 41° of latitude.

(150.) In all places whose mean temperature is below 62°.6, the revival of nature takes place in Spring, in that month whose mean temperature reaches 42°.8, or 46°.4. When the temperature of a month

rises to { 41°.9, the Peach tree (*Amygdalus Persica*) flowers.
46°.8, the Plum tree (*Prunus domestica*) flowers.
51°.8, the Birch tree[*] (*Betula alba*) pushes out its leaves.

Barley, in order to be cultivated advantageously, requires, during ninety days, a mean temperature of from 47°.3 to 48°.2.[†] By adding the mean temperature of the months above 51°.8, that is, the temperatures of those in which deciduous trees vegetate, we shall have a sufficiently exact mean of the continuance and strength of vegetation. As we advance towards the North, the duration of vegetable life is confined to a shorter interval. In the South of France, there are 270 days of the year in which the mean temperature exceeds 51°.8; that is to say, the temperature which the birch requires to put forth its first leaves. At St. Petersburgh, the number of these days is only 120. These two *cycles of vegetation*, so unequal, have a mean temperature which does not differ more than 5°.4.[*]

Method of determining the exact mean of the continuance and strength of vegetation.

(151.) The whole of the preceding observations, it will have been perceived, relate to the temperature of that part of the lower strata of the atmosphere resting on the solid surface of the globe, in the Northern hemisphere, and it now remains to follow the steps of Humboldt in his interesting inquiries respecting the temperature of the Southern Hemisphere.

Temperature of the Southern hemisphere.

(152.) In few departments of Natural Philosophy have Philosophers differed more widely in opinion, than in the comparison of the temperatures of the two hemispheres. From the beginning of the XVIth century, the notion prevailed that the Southern hemisphere was by far the coldest. Mairan and Buffon[†] combated this opinion theoretically, but on inaccurate grounds. Æpinus[‡] established it anew; and the discovery of the vast extent of ice round the Southern pole by the immortal Cook, appeared to widen the difference between these comparative temperatures. Le Gentil, and, particularly, Kirwan,[§] had the merit of having first demonstrated, that the influence of the circumpolar ice extended much less into the temperate zone than was generally admitted. The less distance of the Sun from the winter solstice, and his long continuance in the Northern Signs, act in an opposite manner[‖] on the temperature of the two hemispheres; and as Lambert has demonstrated in his theorem, that the quantity of light which a Planet receives from the Sun increases in proportion to the true anomaly, the different temperatures of the two hemispheres cannot be the effect of unequal radiation. The Southern hemisphere receives the same quantity of light, but the accumulation of heat in it is less,[¶] on account of the emission of the radiant heat which takes place during a long winter. This hemisphere being also in a great measure covered with water, the pyramidal extremities of the continents have there an irregular

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[*] Cotte, *Météorologie*, p. 448; Wahlenberg, *Flor. Lap.* Pl. 51.

[†] Playfair, *Edin. Trans.* vol. v. p. 202; Wahlenberg in Gilbert's *Annalen*, tom. xli.

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[*] The geographical distribution of insects, also, may be made to illustrate the general phenomena of temperature and climate. Latreille has remarked, in his *Introduction à la Géographie Générale des Arachnides et des Insectes, ou des Climats propres à ces Animaux*, that the *temperature* adapted to the developement of one species, is not always proper for that of another; and the *extent* of country which certain species occupy, has necessarily *determinate limits* which they cannot exceed, at least suddenly, without ceasing to exist. The Southern insects of the Western Hemisphere, do not extend so far to the North as in the Eastern. The intelligent Entomologist ought always to take into consideration the height above the sea of the places in which he collects his specimens, and likewise their *mean temperature*, and it may be added, to record precisely their geographical positions.

[†] *Théorie de la Terre*, tom. i.; *Mémoires de l'Acad.* 1765.

[‡] *De Distributione Caloris*, 1761.

[§] *Estimate, &c.*; *Irish Transactions*, vol. viii.; Le Gentil, *Voyage dans l'Inde*, vol. i.

[‖] Mairan, *Mém. Acad.* 1765; Lambert, *Pyrométrie*.

[¶] Prevost, *De la Chaleur Rayonnante*.

climate. Summers of a very low temperature are succeeded, as far as 50° of South latitude, by winters far from rigorous. The vegetable forms also of the torrid zone, says Humboldt, the arborescent ferns, and the orchideous parasites, advance towards 38° and 42° of South latitude. The small quantity of land in the Southern hemisphere,* contributes not only to equalize the seasons, but also to diminish the annual temperature of that part of the globe. This cause, Humboldt thinks, is much more active than that of the small eccentricity of the Earth's orbit. The continents in summer radiate more heat than the seas, and the ascending current, which carries the air of the equinoctial and temperate zones towards the circumpolar regions, acts less in the Southern than in the Northern hemisphere. The cap of ice which surrounds the Pole to the seventy-first and sixty-eighth degree of South latitude, advances more towards the Equator, whenever it meets a free sea; that is, wherever the pyramidal extremities of the great continents are not opposed to it. There is reason, Humboldt thinks, to believe, that this want of dry land would produce an effect still more sensible, if the division of the continents was as unequal in the equinoctial as in the temperate zones.†

The difference of temperature between the two hemispheres, cannot be great near the limit which separates them.

(153.) Theory and experience prove, that the difference of temperature between the two hemispheres, cannot be great near the limit which separates them.‡ Le Gentil had already observed, that the climate of Pondicherry is not warmer than that of Madagascar, at the Bay of Antongel, in 12° of South latitude. Under the parallels of 20, the Isle of France has the same annual temperature, *viz.* 80°.1, as Jamaica and St. Domingo. The Indian Sea between the East coasts of Africa, the Isles of Sonde and New Holland, form a kind of gulf which is shut up to the North by Arabia and Hindostan. The Isothermal lines there appear to go back to the South Pole; for further to the West, in the open sea between Africa and the New World, the cold of the Southern hemisphere already causes itself to be felt from the twenty-second degree, on account of insulated mountains and particular localities. The mean temperature of Rio Janeiro is only 74°.3, whilst, notwithstanding the North winds which bring the cold air of Canada during winter into the Gulf of Mexico, the mean temperatures of Vera Cruz (lat. 19° 11′) and of the Havannah (lat. 23° 10′) are 77°.9. The differences of the two hemispheres become more sensible in the warmest months.

TABLE XXI.

RIO JANEIRO.	Mean Temp.	HAVANNAH.	Mean Temp.
June	68°.0	December	71°.8
July	70.2	January	70.2
January	79.2	July	83.3
February	80.6	August.	83.8

Equality in the division of annual heat, in 34° of North and South latitude.

(154.) The great equality in the division of annual heat in 34° of North and South latitude, is, as Humboldt remarks, very surprising. If we attend to the three continents of New Holland, Africa, and America, we shall find, that the mean temperature of Port Jackson (lat. 33° 51′) is, after the observations of

Hunter, Peron, and Freycinet	66° 7
That of the Cape of Good Hope (lat. 33° 53′)	66.9
That of the City of Buenos Ayres (lat. 34° 36′)	67.5

Two particular temperatures correspond to the same latitude in the Northern hemisphere, according as we compare the concave or convex parts of the Isothermal lines.

(155.) Again, 60°.8 or 69°.8 of annual temperature corresponds to the same latitude in the Northern hemisphere, according as we compare the American* system of climates or the Mediterranean one;—the concave or the convex parts of the Isothermal lines. At Port Jackson, where the Thermometer descends sometimes below the freezing point, the warmest month is 77°.4, and the coldest 56°.8. We find here, continues Humboldt, the summer of Marseilles and the winter of Cairo.† In Van Diemen's Land, corresponding nearly in latitude to Rome, the winters are more mild than at Naples; but the coldness of the summers is such,‡ that the mean temperature of the month of February appears to be scarcely 64°.4, or 66°.2; whilst at Paris, under a latitude more distant from the Equator by 7°, the mean temperature of the month of August is also from 64°.4 to 66°.2, and at Rome above 77°. Under the parallel of 51° 25′ South, the mean temperature of the Malouine Isles is ascertained to be 47°.3. At the same latitude North, we find the mean temperature in Europe from 50° to 51°.8, and in America scarcely from 35°.6 to 37°.4. The warmest and coldest months are at London 66°.2 and 35°.6; at the Malouine Isles 55°.8 and 37°.4. At Quebec, the mean temperature of the water is 14°; at the Malouine Isles 39°.6, though those isles are 4° of latitude further from the Equator than Quebec. These numerical ratios prove, says Humboldt, that, to the parallels of 40° and 50°, the corresponding Isothermal lines are almost equally distant from the Pole in the two hemispheres; and that, in considering only the system of transatlantic climates between 70° and 80° of West longitude, the mean temperatures of the year, under the corresponding geographical parallels, are even greater in the Southern than in the Northern hemisphere.

The division of heat between different parts of the year, gives a particular character to Southern climates.

(156.) The division of heat between the different parts of the year, gives a particular character to Southern climates. In the Southern hemisphere, on the Isothermal lines of 46°.4 and 50°.0, we find summers which in our hemisphere belong only to the Isothermal lines of 35°.6 and 40°.0. The mean temperature is not precisely known beyond 51° of South latitude, but it may be observed, that the eternal snows, which in 71° of North latitude support themselves at the height of 2296 feet above the level of the sea, descend even into the plains, both in South Georgia§ and in Sandwich Land, in 54° and 58° of

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* Humboldt calculates that the dry lands in the two hemispheres are in the ratio of 3 to 1.

† Humboldt remarks, that the dry lands between the tropics are in the two hemispheres as 5 to 4, and without the tropics as 13 to 1.

‡ Prevost, p. 343.

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	Latitude.	Mean Temp.
Natchez	31° 28′	64°.8
Cincinnati	39 06	53.8

†

	Latitude.	Mean Temp.
Cairo	30° 2′	72°.3
Funchal	32 37	68.5
Algiers	36 48	70.0

‡ In Van Diemen's Land the Thermometer descends in February, in the morning, to 45°.5. The mean of mid-day is 60°.8. At Paris it is in August 73°.4. In Van Diemen's Land, in February the mean of the maxima is 78°.8; of the minima 54°.5. At Rome these means are 86° and 64°.5. D'Entrecasteaux, *Voyage*, tom. i.

§ It is the more surprising, says Humboldt, to find, in the Island of Georgia, snow on the banks of the Ocean, because 2° 39′ nearer the Equator, at the Malouine Isles, the mean temperature of the summers is 53°.1, or 9° greater than at the point in our hemisphere in 71° of

South latitude. But these phenomena, however striking they may appear, do not by any means prove that the Isothermal line of 32° is 5° nearer the South Pole than the North Pole. Nor would an equal altitude of the line of perpetual snow in both hemispheres by any means indicate an equal mean temperature of the year. This limit depends particularly[*] on the coldness of summer, and this again on the quick condensations of the vapour caused by the passage of the floating ice. Near the Poles, the foggy state of the air diminishes in summer the effect of the solar irradiation, and in winter that of the radiation of the globe.

Lower strata of the atmosphere is influenced by it.

(157.) The lower strata of the atmosphere, resting upon the aqueous surface of the globe, receive the influence of the temperature of the waters. The sea radiates less absolute heat than the continents; it cools the air by the effect of evaporation; it sends the particles of water cooled and heavier towards the bottom; and it is heated again, or cooled, by the currents directed from the Equator to the Poles, or by the mixture of the superior and inferior strata on the sides of banks.

The mean temperature of the air next the sea, is lower than that of the continental air.

(158.) It is from these causes combined, that, between the tropics, and, perhaps, as far as 30° of latitude, the mean temperatures of the air next the sea are 3°.6 or 5°.4 lower than that of the continental air. Under high latitudes, and in climates where the atmosphere is coolest in winter, much below the freezing point, the isothermal lines rise again towards the Poles, or become convex when the continents pass below the seas.[†]

Four different phenomena of the temperature of the Ocean

(159.) With respect to the temperature of the Ocean, Humboldt refers to four very different phenomena:

1st. The temperature of the water at the surface corresponding to different latitudes, the Ocean being considered at rest, and destitute of shallows and currents.

2d. The decrease of heat in the superimposed strata of water.

3d. The effect of billows on the temperature of the surface of water.

4th. The temperature of currents, which impel, with an acquired velocity, the waters of our zone across the immovable waters of another zone.

Zone of warmest waters.

(160.) The region of warmest waters, observes Humboldt, no more coincides with the Equator than the region in which the waters reach their maximum of saltness. In passing from one hemisphere to another, we find the warmest water between 5° 45′ of North latitude, and 6° 15′ of South latitude. Perrins found their temperature to be 82°.3, Quevedo 83°.5, Churruca 83°.7, and Rodman 83°.8. To the East of the Galapagos Isles, Humboldt found it to be 84°.7. The variations of the mean result do not extend beyond 1°.3; and it is remarkable, as Humboldt observes, that in the parallel of warmest waters, the temperature of the surface of the sea is from 3°.6 to 5°.4 higher than that of the superincumbent air. As we advance from the Equator through the torrid zone, the influence of the seasons on the temperature of the surface of the sea becomes very sensible; but as a great mass of water follows very slowly the changes in the temperature of the air, the means of the months do not correspond at the same epochs in the Ocean and in the air. Besides, the extent of the variations is less in the water than in the atmosphere, because the increase or decrease in the heat of the sea takes place in a medium of variable temperature; so that the *minimum* and the *maximum* of the heat which the water reaches, are modified by the atmospherical temperature of the months which follow the coldest of the warmest months of the year. It is from an analogous cause, continues Humboldt, that in springs which have a variable temperature, for example, near Upsal,[*] the extent of the variations of temperature is only 19°.8, while the same extent in the air from the month of January to August, is 39°.6. In the parallel of the Canary Islands, Von Buch found the minimum of the temperature of the water to be 68°, and the maximum 74°.8. The temperature of the air in the warmest of the coldest months, is, in that quarter, from 64°.4 to 75°.2. In advancing towards the North, we find still greater differences of winter temperature between the surface of the sea and the superincumbent air. The cooled particles of water descend till their temperature reaches 39°.2, the point at which water attains its maximum of density; and hence in 46° and 50° of latitude, in the part of the Atlantic which is nearest to Europe, the *maximum* and *minimum* of heat are

In the water at its surface	68°.0 and 41°.9
In the air from the mean of the warmest and coldest months..........................	66°.2 and 35°.6

The excess in the mean temperature of the water over that of the air, attains its maximum beyond the Polar circle, where the sea does not wholly freeze. If it is true that even in these high latitudes the bottom of the sea contains strata of water which, at the maximum of their Specific Gravity, have 39°.2, or 41° of heat, we may suppose that the water at the bottom contributes to diminish the cooling at the surface. These circumstances have a great influence on the mildness of countries in continents separated from the Pole by an extensive sea.

Temperature of the upper regions of the air.

(161.) We must hasten, however, to conclude this very interesting part of our Essay, by a few observations concerning the distribution of temperature in the upper regions of the air, reserving our remarks respecting the gradations of temperature in ascending to the upper regions of the atmosphere.

Peculiarity of inflexions of Isothermal lines.

(162.) Since the heat of the higher regions of the atmosphere depends on the radiation of the plains, we cannot find under the same geographical parallels, in the transatlantic climates, the Isothermal lines at the same height above the level of the sea, as in the system of European climates. The inflexions which these lines experience, when traced on the surface of the globe, necessarily influence their position in a vertical plane, whether we unite points in the atmosphere placed under the same meridians, or consider only those that have the same latitude. Future inquiries may enable us to trace the Isothermal lines through the different regions of the air; and we may briefly remark, that on the back of the Cordilleras, at 2000 metres of elevation, we find the mean temperature of

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latitude, where the limit of perpetual snow exists at 2296 feet of absolute elevation. But it must be observed, first, That the Malouine Isles are near a continent which is heated in summer. Secondly, That Georgia is covered with mountains, and placed not only in a sea open to the North, but is also under the influence of the perennial ices of Sandwich Land. Thirdly, That in Lapland 20° of latitude produce, in certain local circumstances, 10°.8 of difference in the temperatures of the summers.

[*] Baron Von Buch's *Travels in Lapland*, vol. ii.

[†] Humboldt's *Relat. Histor.* tom. i. p. 67. 230. 242.

[*] Gilbert's *Annalen*, 1812, p. 129.

Calabria and of Sicily. In our temperate zone, in 46° of latitude, we meet, at the same elevation, with the mean temperature of Lapland. In the plains of the Orinoco we find the temperature of the month of August of Rome; at Popayan (2988 feet) the temperature of the same month of Paris; at Quito (4894 feet) that of the month of May; and in the Paramos (5904 feet) the temperature of March, at the same city.

(163.) Humboldt also finds, in prosecuting this interesting inquiry, that every hundred metres of perpendicular height diminishes the mean temperature of the year, by the same quantity that a change of 1° of latitude does in advancing towards the Pole. If we compare only the mean temperature of summer, the first 1000 metres are equivalent to 0°.81 Fahrenheit. From 40° to 50° of latitude, the mean heat of the plains in Europe decreases 12°.6 of Fahrenheit; and this same decrease of temperature takes place on the declivity of the Swiss Alps from 0 to 1000 metres of elevation.

(164.) In the following Table of the distribution of heat, which embraces a general view of Humboldt's results, the temperatures are expressed in degrees of Fahrenheit; the longitudes are reckoned from East to West of the meridian of Greenwich. The mean temperatures of the Seasons have been calculated, so that those of the months of December, January, and February, form the mean temperature of winter. An asterisk (*) is prefixed to those places whose mean temperatures have been most accurately determined, in general, by means of 8000 observations. The Isothermal lines have a convex summit in Europe, and two concave summits in Asia and Eastern America.

General Table of Humboldt's results.

TABLE XXII.

Isothermal Bands.	Names of Places.	Position.			Mean Temperature of the Year.	Distribution of Heat in the different Seasons.				Maximum and Minimum.	
		Latitude.	Longitude.	Height in Feet.		Mean Temperature of Winter.	Mean Temperature of Spring.	Mean Temperature of Summer.	Mean Temperature of Autumn.	Mean Temperature of Warmest Month.	Mean Temperature of Coldest Month.
Isothermal bands from 32° to 41°.	Nain	57° 8′	61° 20′ W.	0	26°.42	−0°.60	23°.90	48°.38	33°.44	51°.80	−11°.20
	*Enontekies	68 30	20 47 E.	1356	26.96	+0.68	24.98	54.86	27.32	59.54	− 0.58
	Hospice de St. Gothard	46 30	8 23 E.	6390	30.38	18.32	26.42	44.96	31.82	46.22	15.08
	North Cape	71 0	25 50 E.	0	32.00	23.72	29.66	43.34	32.08	46.58	22.10
	*Uleo	65 3	25 26 E.	0	35.08	11.84	27.14	57.74	35.96	61.52	7.70
	*Umeo	63 50	20 16 E.	0	33.26	12.92	33.80	54.86	33.44	62.60	11.48
	*St. Petersburgh	59 56	30 19 E.	0	38.84	17.06	38.12	62.06	38.66	65.66	8.60
	Drontheim	63 24	10 22 E.	0	39.92	23.72	35.24	61.24	40.10	64.94	19.58
	Moscow	55 45	37 32 E.	970	40.10	10.78	44.06	67.10	38.30	70.52	6.08
	Abo	60 27	22 18 E.	0	40.28	20.84	38.30	61.88	40.64	—	—
Isothermal bands from 41° to 50°.	*Upsal	59 51	17 38 E.	0	42.08	24.98	39.38	60.26	42.80	62.42	22.46
	*Stockholm	59 20	18 3 E.	0	42.26	25.52	38.30	61.88	43.16	64.04	22.82
	Quebec	46 47	71 10 W.	0	41.74	14.18	38.84	68.00	46.04	73.40	13.81
	Christiana	59 55	10 48 E.	0	42.80	28.78	39.02	62.60	41.18	66.74	28.41
	*Convent of Peyssenburg	47 47	10 34 E.	3066	42.98	28.58	42.08	58.46	42.98	59.36	30.20
	*Copenhagen	55 41	12 35 E.	0	45.68	30.74	41.18	62.60	48.38	65.66	27.14
	*Kendal	54 17	2 46 W.	0	46.22	30.86	45.14	56.84	46.22	58.10	34.88
	Malouine Islands	51 25	59 59 W.	0	46.94	39.56	46.58	53.06	48.46	55.76	37.40
	*Prague	50 5	14 24 E.	0	49.46	31.46	47.66	68.90	50.18	—	—
	Gottingen	51 32	9 53 E.	456	46.94	30.38	44.24	64.76	48.74	66.38	29.66
	*Zurich	47 22	8 32 E.	1350	47.84	29.66	48.20	64.04	48.92	65.66	26.78
	*Edinburgh	55 57	3 10 W.	0	47.84	38.66	46.40	58.28	48.56	59.36	38.30
	Warsaw	52 14	21 2 E.	0	48.56	28.76	47.48	69.08	49.46	70.34	27.14
	*Coire	46 50	9 30 E.	1876	48.92	32.36	50.00	63.32	50.36	64.58	29.48
	Dublin	53 21	6 19 W.	0	49.10	39.20	47.30	59.54	50.00	61.16	35.42
	Berne	46 5	7 26 E.	1650	49.28	32.00	48.92	66.56	49.82	67.28	30.56
	*Geneva	46 12	6 8 E.	1080	49.28	34.70	47.66	64.94	50.00	66.56	34.16
	*Manheim	49 29	8 28 E.	432	50.18	38.80	49.64	67.10	49.82	68.72	33.44
	Vienna	48 12	16 22 E.	420	50.54	32.72	51.26	69.26	50.54	70.52	26.60
Isothermal bands from 50° to 59°.	*Clermont	45 46	3 5 E.	1260	50.00	34.52	50.54	64.40	51.26	66.20	28.04
	*Buda	47 29	19 1 E.	494	51.08	33.98	51.08	70.52	52.34	71.60	27.78
	Cambridge, (U. S.)	42 25	71 3 W.	0	50.36	33.98	47.66	70.70	49.82	72.86	29.84
	*Paris	48 50	2 20 E.	222	51.08	38.66	49.28	64.58	51.44	65.30	36.14
	*London	51 30	0 5 W.	0	50.36	39.56	48.56	63.14	50.18	64.40	37.76
	Dunkirk	51 2	2 22 E.	0	50.54	38.48	48.56	64.04	50.90	64.76	37.75
	Amsterdam	52 22	4 50 E.	0	51.62	36.86	51.62	65.84	51.62	66.92	35.42
	Brussels	50 50	4 22 E.	0	51.80	36.68	53.24	66.20	51.08	67.28	35.60
	*Franeker	52 36	6 22 E.	0	51.80	36.68	51.08	67.28	54.32	69.08	32.90
	Philadelphia	39 56	75 16 W.	0	53.42	32.18	51.44	73.94	56.48	77.00	32.72
	New York	40 40	73 58 W.	0	53.78	29.84	51.26	79.16	54.50	80.78	25.34
	*Cincinnati	39 6	82 40 W.	510	53.78	32.90	54.14	72.86	54.86	74.30	30.20
	St. Malo	48 39	2 1 W.	0	54.14	42.26	52.16	66.02	55.76	66.92	41.74
	Nantes	47 13	1 32 W.	0	54.68	40.46	54.50	68.54	55.58	70.52	39.02
	Pekin	39 54	116 27 E.	0	54.86	26.42	56.30	82.58	54.32	84.38	24.62
	*Milan	45 28	9 11 E.	390	55.76	36.32	56.12	73.04	56.84	74.66	36.14
	Bourdeaux	44 50	0 34 W.	0	56.48	42.08	56.48	70.88	56.30	73.04	41.00

Isothermal Bands.	Names of Places.	Position.			Mean Temperature of the Year.	Distribution of Heat in the different Seasons.				Maximum and Minimum.	
		Latitude.	Longitude.	Height in Feet.		Mean Temperature of Winter.	Mean Temperature of Spring.	Mean Temperature of Summer.	Mean Temperature of Autumn.	Mean Temperature of Warmest Month.	Mean Temperature of Coldest Month.
Isothermal bands from 59° to 63°.	Marseilles..................	43° 17′	5 22 E.	0	59°.00	45°.50	57°.56	72°.50	60°.08	74°.66	44°.42
	Montpellier	43 36	3 52 E.	0	59.36	44·06	56.66	75.74	60.98	78.08	42.08
	*Rome..................	41 53	12 27 E.	0	60.44	45.86	57.74	75.20	62.78	77.00	42.26
	Toulon..................	43 7	5 50 E.	0	62.06	48.38	60.80	75.02	64.40	77.00	46.40
	Nangasacki	32 45	129 55 E.	0	60.80	39.38	57.56	82.94	64.22	86.90	37.40
	*Natchez	31 28	90 30 W.	180	64.76	48.56	65.48	79.16	66.02	79.70	46.94
Isothermal bands from 68° to 77°.	*Funchal	32 37	16 56 W.	0	68.54	64.40	65.84	72.50	72.32	75.56	64.04
	Algiers..................	36 48	3 1 E.	0	69.98	61.52	65.66	80.24	72.50	82.76	60.08
Isothermal bands from above 77°.	*Cairo	30 2	31 18 E.	0	72.32	58.46	73.58	85.10	71.42	85.82	56.12
	*Vera Cruz..................	19 11	96 1 W.	0	77.72	71.96	77.90	81.50	78.62	81.86	71.06
	*Havannah	23 10	82 13 W.	0	78.08	71.24	78.98	83.30	78.98	83.84	69.98
	*Cumana..................	10 27	65 15 W.	0	81.86	80.24	83.66	82.04	80.24	84.38	79.16

On the Mean Temperature of the Equator.

(165.) The determination of the mean temperature of the Equator,* is a Meteorological element of the greatest importance and value. If we survey the magnificent line to which this part of our inquiry extends, we shall immediately perceive that many obstacles, besides those of a Physical kind, present themselves at the very threshold of our investigation. In the Equatorial regions of America, it passes through a region almost unknown, and in which the light of civilization and liberty has been but recently kindled; and in its passage across the still more inhospitable deserts of Africa, obstacles still more formidable are presented. Nor would observations at Sumatra, Borneo, Celebes, and Gilolo, unless made on a very extended scale, and under circumstances variously modified, determine, with any tolerable approach to precision, the average temperature of this great line. The Ocean, too, occupies by far the greatest portion of the Equatorial regions, the land occupying but 80 degrees of the great circle, and water the remaining portion of 280 degrees. Under these circumstances, we cannot feel surprised at the remark made by Humboldt, that at the present day we are not acquainted with more than one mean temperature observed with any degree of precision between the parallels of 3° North and 3° South, and that is of St. Louis de Maranham in Brazil, 2° 29′ South latitude, made by Colonel Antonio Pererira. Deprived thus of actual observations at the Equator, Philosophers have endeavoured to deduce its mean temperature from observations made at a distance from it. Mayer, for example, by knowing the mean temperature under two different parallels, endeavoured by means of an empirical equation to deduce the mean Equatorial temperature. This he estimated at 84°, and in this value he was followed by Kirwan.

Known only between the parallels of 3° North, and 3° South.

(166.) But it is evident, that observations made in the temperate regions of Europe, could not supply the mean temperature of a line, situated so remotely from them, and it became therefore desirable to collect the mean temperatures of places situated as nearly as possible to it. Accordingly Humboldt collected his elements in the Old and New World, and among them are the following:

Humboldt's observations.

TABLE XXIII.

Old World.	Latitude.	Mean Temp.	New World.	Latitude.	Mean Temp.
Senegambia ..	15° 0′	79°.07	Cumana	10° 27′	81°.86
Madras......	13 5	80.42	Antilles......	17 0	81.05
Batavia......	6 12	80.42	Vera Cruz....	19 11	78.08
Manilla......	14 36	78.08	Havannah....	23 10	78.08

(167.) From a review of all the circumstances connected with these places, Humboldt was led to adopt 81°.5 as the mean temperature of the Equator; and our learned contemporary, Dr. Brewster, employed it, with some modifications, as the coefficient of his formula for mean temperature. In the second volume of the *Transactions of the Astronomical Society of London*, however, Mr. Atkinson, in an elaborate Paper on Astronomical and other Refractions, has questioned the accuracy of Humboldt's conclusion; and we shall, therefore, present to our readers the grounds of his objections.

(168.) Let t, t', t'', represent, says Mr. Atkinson, the observed mean temperatures in the latitudes l, l', l'', &c.; and if the mean temperature be supposed to vary as any function $\varphi\,(l)$ of the latitude, we shall obtain the following equations:

Doubted by Mr. Atkinson.

$$\begin{aligned} x \,.\, \varphi\,(l) + z &= t \\ x \,.\, \varphi\,(l') + z &= t' \;..........\; \text{(A)} \\ x \,.\, \varphi\,(l'') + z &= t'', \\ \text{\&c.} \qquad & \text{\&c.} \end{aligned}$$

x and z being unknown, but constant quantities, to be determined from the equations.

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* The determination of what may with propriety be termed an *Isothermal Equator*, or *Curve of greatest heat*, will, if the future progress of Meteorology be successful, open a beautiful and instructive object of inquiry.

(169.) If the form of the function (φ) were rightly assumed, and the observations made of the temperature were accurate, the resolution of any two of the above equations would determine the values of x and z. Neither of these conditions can, however, be fulfilled with accuracy, and we must therefore be contented with a close approximation. To accomplish this, we must first observe that the difference between the first and second equations gives

$$x\{\varphi(l) - \varphi(l')\} = t - t',$$

from which we deduce

$$x = \frac{t - t'}{\varphi(l) - \varphi(l')} \dots\dots\dots (B).$$

This value for x being substituted in the first equation, we obtain by transposition

$$z = t - \frac{(t - t') \cdot \varphi(l)}{\varphi(l) - \varphi(l')} \dots\dots\dots (C).$$

(170.) Hence the values both of x and z being found in functions of the observed temperature, will furnish the necessary elements for the determination of the function (φ). This function, however, is probably of a complicated nature, it being obvious that the mean temperature of any place must be influenced by the state of those countries from which the prevailing winds at that place blow;—by the extent and nature of the land that surrounds it, by the proximity of open seas, or of seas that are frozen, and by a variety of other causes. The obliquity of the Sun's rays is, however, the principal cause of the diminution of temperature, as we proceed from the Equator towards either Pole; but this obliquity is dependent on the latitude; and hence we may consider the variation in the temperature, as some function of the latitude, as has already been done in the equations of condition, and afterwards endeavour to estimate what correction must be applied on account of such disturbing causes, as may exist in the place selected for consideration. Or, if we have a sufficient number of good observations within a given district, we may, says Mr. Atkinson, by a judicious application of the powers of calculation, deduce a formula, which shall present in its results a near approximation for any other place within the same district, and which may even be extended beyond it, without producing any material error.

(171.) If now we suppose with Humboldt, that $\varphi(l) = \cos^2 l$,* the equations before deduced for the values of x and z, will assume the forms of

$$x = \frac{t - t'}{\cos^2 l - \cos^2 l'}$$

and

$$z = t - \frac{(t - t')\cos^2 l'}{\cos^2 l - \cos^2 l'};$$

and if we apply these equations to the mean temperatures of Cumana and Fort Churchill, as recorded by Humboldt in his Paper on Isothermal lines, the values of which are respectively 81°.86, and 25°.3, we shall obtain for x the value of 80°.53, and for z that of 3°.98 nearly.

(172.) These values being substituted in the general equation, give

$$80^\circ.53 \cos^2 l + 3^\circ.98 = t;$$

so that when the latitude vanishes, the value of t becomes

$$80^\circ.53 + 3^\circ.98 = 84^\circ.51,$$

which is hence the mean temperature of the Equator according to the observations made at Cumana and Fort Churchill. If, again, we suppose the value of l to be 90°, we obtain for the mean temperature of the pole 3°.98.

Mr. Atkinson's observations.

(173.) Mr. Atkinson next endeavours to obtain a formula of the same kind by means of the four observations contained in the following Table, drawn from the same Paper of Humboldt.

TABLE XXIV.

Names of Places.	Latitude.	Mean Temperature.
Cumana	10°27′	81°.86
Antilles	17 0	81.05
Vera Cruz	19 11	78.08
Havannah............	23 10	78.08

and for this purpose, he assumes

$$(80^\circ.53 + x')\cos^2 l + 3^\circ.98 + z' - t = \mathrm{E},$$

some unknown error, x' and z' being corrections so adapted to the formula, as to make it agree with the temperatures of the places last recorded. Applying this formula to each, we shall obtain the following equations of condition:

$$.967\,x' + z' + 0^\circ.00 = \mathrm{E}'$$

$$.915\,x' + z' - 3.42 = \mathrm{E}''$$

$$.892\,x' + z' - 2.27 = \mathrm{E}'''$$

$$.845\,x' + z' - 6.03 = \mathrm{E}'''',$$

and if we regard the sum of the squares of the errors E′, E″, E‴, E⁗, as a minimum, and deduce the values of x' and z' according to the method of minimum squares, we shall have $x' = -40.664$, and $z' = 89.72$. Hence the formula which best represents the observations made at Cumana, the Antilles, Vera Cruz, and the Havannah, if the law of variation be as $\cos^2 l$, is

$$39^\circ.866 \cos^2 l + 43^\circ.7 = t.$$

This will give for the mean temperature of the Equator, where l vanishes, $t = 83^\circ.566$; and for the Pole, when the $\cos l$ becomes zero, $t = 43^\circ.7$; a result altogether inadmissible, since it makes the temperature of the Pole 5°.8 greater than that of Quebec. Both the numerical elements of the formula require therefore modification.

(174.) To obtain a formula which shall agree with as many places as possible between Cumana and Fort Churchill, Mr. Atkinson presents the following equations of condition.

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* Mr. Atkinson found it necessary to adopt the same law of variation for the temperature as that employed by Humboldt.

TABLE XXV.

Names of Places.	North Latitude.	Equations of Condition.	Observed Mean Temperature.	Temperature by the Formula.	Difference.*
Cumana	10° 27′	$.967\,x'+z'+0°.00=E^{\text{i}}$	81°.86	85°.26	+3°.40
Antilles	17 0	$.915\,x'+z'-3.42=E^{\text{ii}}$	81.05	80.79	−0.26
Vera Cruz	19 11	$.892\,x'+z'-2.27=E^{\text{iii}}$	78.08	78.88	+0.80
Havannah	23 10	$.846\,x'+z'-6.03=E^{\text{iv}}$	78.08	74.91	−3.17
Natchez	31 28	$.728\,x'+z'-2.23=E^{\text{v}}$	64.80	64.91	+0.11
Philadelphia	39 56	$.588\,x'+z'-3.57=E^{\text{vi}}$	54.90	53.06	−1.84
Cincinnati	39 6	$.602\,x'+z'-1.12=E^{\text{vii}}$	53.60	54.28	+0.68
New York	40 40	$.575\,x'+z'-3.49=E^{\text{viii}}$	53.80	51.99	−1.81
Cambridge	42 25	$.545\,x'+z'-2.53=E^{\text{ix}}$	50.40	49.42	−0.98
Quebec	46 47	$.469\,x'+z'-0.16=E^{\text{x}}$	41.90	42.95	+1.05
Nain	57 10	$.294\,x'+z'+1.25=E^{\text{xi}}$	26.40	28.10	+1.70
Fort Churchill	59 2	$.265\,x'+z'-0.00=E^{\text{xii}}$	25.30	25.62	+0.32

The application of minimum squares to these equations, will give $x'=4°.38$, and $z'=-0°.84$. The formula, therefore, which best represents the whole of these mean temperatures, on the hypothesis adopted by Humboldt after Mayer, that the temperature varies as the square of the cosine of the latitude, is

$$84°.91\cos^2 l+3°.14=t,$$

and which gives for the Equatorial temperature 88°.05, and for the Polar 3°.14.

(175.) The next step of Mr. Atkinson's inquiry is, to deduce the mean temperature of the Equator from the supposition that the law of variation is not as the square of the cosine, but as some other function of the latitude; and for this purpose he adopts $\cos^n l$ to represent it, the exponent n being some unknown but constant quantity, to be determined by subsequent investigations. In this case the formulæ (B) and (C) will assume the form of

$$x=\frac{t-t'}{\cos^n l-\cos^n l'}\;\ldots.(D),$$

and
$$z=t-\frac{(t-t')\cos^n l}{\cos^n l-\cos^n l'}\;\ldots.(E).$$

(176.) These values being substituted for x and z in the third of the conditional equations (A) will give

$$\frac{(t-t')\cos^n l''}{\cos^n l-\cos^n l'}+t-\frac{(t-t')\cos^n l}{\cos^n l-\cos^n l'}=t'',$$

and from which we deduce

$$\frac{t-t''}{t-t'}=\frac{\cos^n l-\cos^n l''}{\cos^n l-\cos^n l'},$$

a function from which an approximative value of n may be obtained, in terms of the latitudes l, l', l'', and of the observed temperatures t, t', t''.

(177.) To obtain this value of the exponent n, Mr. Atkinson selects three observations near the Equator, three near the middle regions of North America, and other three towards the Northern parts of the same great country, as in the following Table:

TABLE XXVI.

Names of Places.	North Latitude.	Observed Temperature.
Cumana	10° 27′	81°.86
Antilles	17 0	81.05
Vera Cruz	19 11	78.08
Philadelphia	39 56	54.90
Cambridge	42 25	50.40
New York	40 40	53.80
Nain	57 10	26.40
Okak	57 20	29.80
Fort Churchill	59 2	25.30

(178.) These temperatures and latitudes Mr. Atkinson has combined by *threes*, and deduced the value of n for each combination. The following are the results:

Cumana Philadelphia Nain } $n=0°.91$	Cumana Cambridge Okak } $n=1°.70$	Cumana New York Fort Churchill } $n=1°.20$
Antilles Cambridge Okak } $n=2.06$	Antilles New York Fort Churchill } $n=1.55$	Antilles Philadelphia Nain } $n=1.30$
Vera Cruz New York Fort Churchill } $n=1.80$	Vera Cruz Philadelphia Nain } $n=1.10$	Vera Cruz Cambridge Okak } $n=1.06$

(179.) These form of course only a part of the system of combinations which might be framed, but there is little probability that the mean of the whole would differ more than three or four hundredth parts from the mean of the nine values of n, and which is found to be $1°.46$, or $\frac{3}{2}$ nearly.

(180.) This value of n being substituted in the formulæ (D) and (E), will produce the equations

$$x=\frac{t-t'}{\cos^{\frac{3}{2}} l-\cos^{\frac{3}{2}} l'},$$

and
$$z=t-\frac{(t-t')\cos^{\frac{3}{2}} l}{\cos^{\frac{3}{2}} l-\cos^{\frac{3}{2}} l'}.$$

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[*] The last three columns have been added by Mr. Atkinson, to show the errors of the formula resulting from the equations of condition; and from which we may readily perceive the degree of reliance that ought to be placed on it.

(181.) To apply these formulæ, Mr. Atkinson adopts the observations made at the Antilles and Fort Churchill, and finds $x = 98^\circ.48$, and $z = -11^\circ.05$; and hence the formula for the temperature will become

$$91^\circ.48 \cos^{\frac{3}{2}} l - 11^\circ.05 = t.$$

(182.) The general expression for finding the equations of condition will therefore become

$$(98^\circ.48 + x') \cos^{\frac{3}{2}} l - 11^\circ.05 + z' - t = E,$$

which being applied to each of the places at, or near, the level of the sea, whose mean temperature is known by observation, will furnish as many equations of condition as there are places, as in the following Table:

TABLE XXVII.

Names of Places.	North Latitude.	Observed Temperature.	Equations of Condition.	References for Temperature.
Cumana	10° 27′	81°.86	$.9752\,x' + z' + 3^\circ.13 = E_1$	*Edin. Phil. Jour.* vol. iii. p. 263.
Antilles	17 00	81.05	$.9352\,x' + z' + 0.00 = E_2$	Ditto.
Vera Cruz	19 11	78.08	$.9179\,x' + z' + 1.26 = E_3$	Ditto.
Havannah	23 10	78.08	$.8815\,x' + z' - 2.32 = E_4$	Ditto.
Oratava	28 25	69.80	$.8248\,x' + z' + 0.38 = E_5$	Ditto. p. 256.
Natchez	31 28	64.80	$.7877\,x' + z' + 1.73 = E_6$	Ditto.
Williamsburg	38 08	58.00	$.6976\,x' + z' - 0.35 = E_7$	Ditto. p. 257.
Philadelphia	39 56	54.90	$.6715\,x' + z' + 0.17 = E_8$	Ditto.
New York	40 40	53.80	$.6606\,x' + z' + 0.21 = E_9$	Ditto.
Cambridge	42 25	50.40	$.6343\,x' + z' + 1.02 = E_{10}$	Ditto.
Ipswich	42 38	50.00	$.6310\,x' + z' + 1.09 = E_{11}$	Ditto.
Nain	57 10	26.40	$.3992\,x' + z' + 1.87 = E_{12}$	Ditto.
Okak	57 20	29.80	$.3965\,x' + z' - 1.80 = E_{13}$	Ditto.
Fort Churchill	59 02	25.30	$.3691\,x' + z' + 0.00 = E_{14}$	Ditto. p. 265.

(183.) By the application of minimum squares, we find $x' = -1^\circ.40$, and $z' = +0^\circ.52$; and therefore the formula that harmonizes best with the whole of the preceding observations, is

$$97^\circ.08 \cos^{\frac{3}{2}} l - 10^\circ.53 = t,$$

which furnishes for the mean temperature of the Equator 86°.55, and for that of the Pole − 10°.53.

Attempt to deduce the mean temperature of the Equator, from places situated above the level of the sea.

(184.) Such is the result of this new expression for the law of the variation of the temperature adopted. But Mr. Atkinson truly remarks, that could we discover any near approximation to the law by which the altitude and the corresponding variation of temperature are connected, we might, in all probability, deduce the mean temperature of the Equator from a few of the places situated above the level of the sea, and whose latitudes are less than any previously employed. By a very laborious investigation, founded on an expression for the diminution of temperature, and which will be given in the section of our Paper devoted to that interesting inquiry, together with the Table of results deduced from it, Mr. Atkinson has found, that from the limits of perpetual snow at the Equator to Winter Harbour in Melville's Island, the formula

$$97^\circ.08 \cos^{\frac{3}{2}} l - 10^\circ.53 - \frac{h}{251 + \frac{h}{200}} = t,$$

at the elevation h in the free atmosphere, will correspond in its results very nearly with the mean temperatures observed. Hence he observes, that a formula which answers so very nearly the whole way from latitude 10° 27′ North to 74° 47′ North, will not be far wrong if it be extended to the Equator itself. The law, also, he continues, which holds so nearly the whole way from the level of the sea up to more than 15,000 feet of elevation, cannot well lead to any error of consequence in the first 3000 or 4000 feet of altitude. We have, therefore, only to calculate by the formula, what corrections must be applied, on account of latitude and altitude, to the observed mean temperature of any place, situated not too far from the Equator, and whose elevation above the level of the sea does not exceed 4000 feet, to enable us to find the mean temperature of the Equator itself, with almost as great a degree of accuracy as that with which the mean temperature of the place of observation has been obtained. There are only nine places in South America whose mean temperature has been given by Humboldt, and whose latitude is less than 11°, and altitude below 3500 feet. By applying this method to each of them, Mr. Atkinson has obtained the results of the following Table:—

TABLE XXVIII.

Names of Places.	Height.	Latitude.			Observed Mean Temperature.	Correction on account of Height.	Correction on account of Latitude.	Temperature of Equator, as deduced from each Place.
					Fahr.	Fahr.	Fahr.	Fahr.
La Plata	3437	2°	24′	N.	74°.66	+12°.81	+0°.13	87°.60
Neiva	1702	3	10	—	77.00	6.56	0.22	83.78
Tocayma	1581	4	16	—	81.50	6.10	0.40	88.00
Carthago	3149	4	46	—	74.84	11.80	0.50	87.14
Tomependa	1279	5	33	S.	78.44	4.96	0.68	84.08
Antioquia	1666	7	01	N.	77.00	6.42	1.09	84.51
Caripe	2959	9	50	—	65.30	11.13	2.13	78.56
Cumana	....	10	27	—	81.86	......	2.41	84.27
Caraccas	2906	10	31	—	69.44	10.94	2.44	82.82
							Mean =	84.53

Consequent temperatures of the Equator.

(185.) The mean temperature, therefore, would appear to be 84°.53; but if Caripe be excluded, as it seems probable it ought to be, from its differing so much from any of the rest, the mean among the remaining eight would be 85°.275. And should it be thought that those places whose altitude is below 2000 feet are better adapted to give a correct result, by taking the mean of the five places so situated, we shall obtain 84°.93 for the mean temperature of the Equator.

Mr Atkinson's general results.

(186.) The general results of Mr. Atkinson are, therefore, as follows:

1°. *The whole of Humboldt's observations in both North and South America, at or near the level of the sea, indicate that the mean temperature of the Equator, at the same level, is* 86°.55 *Fahrenheit.*

2°. *All the observations, nine in number, made within* 11° *of the Equator, where the height does not exceed* 3500 *feet, indicate that its temperature is* 84°.53. *But if Caripe be excluded, the remaining eight give* 85°.275 *for the mean temperature of the Equator.*

3°. *If those places only be taken which are within the same limits, and whose height is less than* 2000 *feet, they indicate that its mean temperature is* 84°.93.

Humboldt's reply to Atkinson's objections.

(187.) Humboldt, in referring to the objections of Mr. Atkinson, has entered on the consideration of the question, with all that amplitude and generality for which he is so deservedly celebrated. In an able Paper *On the Temperature of the different Parts of the Torrid Zone at the Level of the Sea*, published in the *Annales de Chimie* for September, 1826, he discusses particularly the question of the mean Equatorial temperature, and adduces strong and plausible reasons that he has not underrated the temperature of that line. If the Equatorial temperature, says he, were that of the Equatorial zone surrounding the whole globe, and bounded by the parallels of 3° North and 3° South, we must first examine the temperature of the Equatorial Ocean, forming as it does so very considerable a proportion of the Earth's circumference in this region. The mean temperature of the Ocean, says Humboldt, between the limits alluded to, varies in general between 80°.24 and 82°.4. I say in general, continues the distinguished traveller, because we sometimes find between these limits maxima restricted to zones scarcely a degree wide, and whose temperature rises in different longitudes, from 83°.7 to 84°.7. I have observed this last temperature, says he, which may be regarded as very high in the Pacific Ocean, to the East of the Galapagos Islands, and recently M. Baron Dirckinc, of Holmfeldt, a well-informed officer of the Danish Navy, who, at my request, made a great number of thermometrical observations, has found (in latitude 2° 5′ North, and longitude 81° 54′ West) almost in the parallel of Punta Guascama, the surface of the water at 87°.1. These maxima, however, do not belong to the Equator itself. They occur sometimes to the North, and sometimes to the South of it, and often between the latitudes of 2½°. and 6°. The great circle which passes through the points where the waters of the Ocean are the warmest, cuts the Equator at an angle which seems to vary with the Sun's declination. In the Atlantic Ocean we may sometimes even pass from the Northern to the Southern temperate zone, in the zone of the warmest waters, without observing the Thermometer to rise above 82°.4. The maxima are according to

The maximum temperatures do not belong to the Equator itself.

Perrins	82°.76
Churrucca	83.66
Quevedo	83.48
Rodman	83.84
Dr. Davy	82.58
Mean	83.26

The air resting on the Equatorial waters is colder than the Ocean.

(188.) The air also which rests upon these Equatorial waters is from 1°.8 to 2°.7 colder than the Ocean; and it results from these facts, that over nearly five-sixths of the circumference of the globe, the Equatorial aqueous zone, instead of presenting a mean temperature of 84°.5, has probably not one of 83°.3; and Mr. Atkinson himself admits, that the union of the aqueous and continental parts tends to diminish the mean temperature of the Equator.

Humboldt's further remarks on Atkinson.

(189.) In alluding to Mr. Atkinson's investigations to deduce the mean temperature of the Equator from the assumed law of increase of heat from the Pole to the Equator, by the observations made at Cumana, and from the temperatures observed on the declivity of the Cordilleras, to a height of 500 toises, corrected according to his hypotheses for the latitude, and for the progressive diminution of heat in a vertical plane, Humboldt remarks, that in studying in all its generality the problem of the distribution of heat on the surface of the globe, and in freeing it of the accessory considerations of localities, (for example of the effects of the configuration, the colour and the geographical relations of the soil; of those of the predominance of certain winds, of the proximity of seas, of the frequency of clouds and fogs, and of the nocturnal radiation towards a sky more or less serene,) we shall find that the mean temperature of a station depends on the different ways in which the influence of the meridian altitude of the Sun manifests itself. This altitude determines at once the duration of the semi-diurnal arcs, the length and the transparency of the portion of the atmosphere which the rays traverse before reaching the horizon; the quantity of the absorbed or heating rays, (a quantity which augments rapidly when the angle of incidence, reckoned from the level of the surface, increases;) and, lastly, the number of solar rays which a given horizon embraces. The law of Mayer, with all the modifications that have been introduced into it, is an empirical law, which represents the generality of the phenomena by approximation, and often in a satisfactory manner, but it cannot be employed against the testimony of direct observations. If the surface of the globe, from the Equator to the parallel of Cumana, was a desert like that of Sahara, or a Savannah uniformly covered with grass like the Llanos of Calabozo and of Apure, there would undoubtedly be an increment of mean temperature from 10½° of latitude to the Equator, but it is very probable that this increase does not amount to 2½° of Fahrenheit. If I have fixed, continues M. Humboldt, the mean temperature of the Equator in round numbers at 81½°, it was to attribute to the Equatorial zone from 3° North to 3° South the mean temperature of Cumana 81°.86 This city, surrounded with arid sands, situated under a sky always serene, and whose thin vapours seldom resolve themselves into rain, possesses a more burning climate than all the places which surround it, and which like it are on the level of the sea. In advancing Southward in America, towards the Equator, by the Orinoco and Rio Negro, the heat diminishes, not on account of the elevation of the soil, which from the fort of St. Carlos is very little, but on account of the forests, the frequency of rains, and the transparency of the atmosphere.

Remarks on the law of Mayer.

Remarks relative to Cumana.

Examples of mean temperature.

(190.) Below 10½° of latitude, we know only the mean temperatures of

	Latitude.	Fahr.
Batavia	6° 12′ S.	80°.42
Cumana	10 27 N.	81.86

(191.) Between 10½° of latitude, and the extremity of the torrid zone, we have

	Latitude.	Fahr.
Pondicherry	11° 55′ N.	85°.28
Madras	13 4	80.42
Manilla	14 36	78.08
Senegal	15 53	79.70
Bombay	18 56	80.06
Macao	22 12	73.94
Rio Janeiro	22 54 S.	74.30
The Havannah	23 9 N.	78.26

And after the observations of Pereira,

Maranham	2 29 S.	81.32

(192.) Hence it appears that the only place in the Equinoctial regions, whose mean temperature exceeds 81°.86, is Pondicherry, whose climate can no more serve to characterise the Equatorial region than the Oasis of Mourzouk, where the unfortunate Ritchie and Captain Lyon assure us that they saw, during whole months, (perhaps from the sand disseminated in the air,) the Thermometer at 117° and 128°, can characterise the climate of the temperate zone in the North of Africa. The three or four degrees nearest to the Equator, continues Humboldt, are a *terra incognita* for climatology. We are still ignorant of the mean temperatures of Grand Para, Guayaquil, and even Cayenne.

Humboldt concludes that the mean temperature never reaches the quantity assigned by Mr. Atkinson.

(193.) From every consideration, therefore, M. Humboldt concludes that the Equatorial temperature never reaches 84°.56, as is supposed by Mr. Atkinson. Father Beza, says he, the first traveller who recommended observations on the warmest and coldest periods of the day, believed that he had found in 1686 and 1699, in comparing Siam, Malacca, and Batavia, "that the heat is not greater under the Equator than under 14° of latitude." I am of opinion, continues Humboldt, that there is a difference, but that it is very small, and marked by the effect of many causes, which act simultaneously on the mean temperature of a place. The observations hitherto collected do not afford us any measure of a progressive increase between the Equator and the latitude of Cumana.

Necessity for further observations.

(194.) There can be little doubt but the numerical elements we possess relating to the tropical regions in general, require still further observations to correct and improve them; but there is one circumstance connected with Mr. Atkinson's calculations, which merits consideration. Mr. Atkinson has confined his investigations entirely to the temperatures of the New World, and omitted those of the Old World; and although Humboldt has shown that the temperature of the Equatorial regions is nearly the same under all meridians, yet Dr. Brewster has proved that the gradations of temperature from the Equator to the Poles are not the same in the Old and New Worlds; and it is probable, that a set of observations made in different latitudes of the Eastern hemisphere, would furnish some other result for the mean temperature of the Equator. Humboldt, on the contrary, has generalized his views, and formed his estimate of the mean Equatorial temperature from observations made under different meridians, and situated as nearly as possible to the Equator. Indeed of the two, observations made in the Old World are to be preferred to those in the New, because the distribution of heat is subject to fewer anomalies. Still the investigations of Mr. Atkinson are of a nature to make us pause on the inquiry, and not to be hasty in adopting a numerical value for an element of so important a kind as the mean temperature of the Equator. Dr. Brewster, however, is decidedly of opinion that Humboldt has not underrated the mean temperature of that line, and adduces several observations in support of his opinion in the VIth volume of the *Edinburgh Journal of Science.*

(195.) His first series of observations are for Ceylon, as follows:

	Mean Temp.
Trincomalee	80°.56
Point de Galle	81.10
Colombo	80.75
Kandy*	78.50
Ditto, according to Dr. Davy	79.20

If now we deduce the Equatorial temperature from

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* A correction of 5°.7 is added for altitude, according to Mr. Atkinson's formula.

Dr. Brewster's attempt to deduce the mean temperature of the Equator.

these observations, either by the formula Eq. temp. $= \frac{T}{\cos L}$, according to the principle of Brewster's formula, or by the formula Eq. temp $= \frac{T}{\cos^2 L}$, according to the principle of Mayer's formula, we shall obtain the following results:

	Mean Temperature of Equator.	
	Eq. temp. $= \frac{T}{\cos L}$	Eq. temp. $= \frac{T}{\cos^2 L}$
Trincomalee	81°.46	82°.37
Point de Galle	81.55	82.02
Colombo	81.34	81.93
Kandy	79.14	79.78
Do. according to Dr. Davy	79.34	80.49
Means	80.66	81.32

Mean of both = 80°.99.

Deduction for Ceylon.

It follows, therefore, from the Ceylon observations, that the mean temperature of the Equator is less than 81½°.

For Batavia and the Sandwich Islands.

(196.) By a series of observations furnished by Professor Moll, of Utrecht, for Batavia, Dr. Brewster finds the mean temperature of the Equator to be 81°.32; and from a series of observations made at the Sandwich Islands, he also deduces 81°.04 for the measure of the same element.

Further deductions from observations made at Prince of Wales's Island, Singapore, and Malacca.

(197.) In the VIIIth volume of the same *Journal*, Dr. Brewster has given the results of observations made at Prince of Wales's Island, within 5° of the Equator, and at Singapore and Malacca, within 1° and 2° of the same line. At Singapore, according to the observations of Colonel Farquhar, the

Mean annual temperature at 6 A.M. and 6 P.M. for 1822 = 79° 45′
——————— 12h noon ——————— 84 00

and to deduce the mean daily temperature from these, Dr. Brewster applies certain corrections deduced from the hourly observations made at Leith Forth for 1824 and 1825; *viz.* that the mean daily temperature exceeds the mean of the morning and evening observations by 0.29, and is less than that of noon by 2°.51, (the grounds of which corrections will hereafter be explained,) we shall find the mean Equatorial temperature to be 80°.47.

Corrections applied to them.

Objections obviated.

(198.) It may be objected, however, that corrections deduced from a Northern climate marked with the vicissitudes of summer and winter, cannot be strictly applied to the tropical regions of the Earth, where the variations in the monthly temperature are so exceedingly small. To meet this objection, Dr. Brewster has deduced the corrections from the hourly temperatures of the three summer months, during which the variations of the daily curve must have a greater resemblance to those of the torrid zone. These corrections are − 3.08 and − 3.00, and, though differing from those used above, produce, as will be seen, very little difference in the mean results.

Mean Temperature of the Pole.

Mean temperature of the Pole.

(199.) The probable mean temperature of the Pole is an interesting problem in Meteorological inquiry. In the absence of all positive observations, we are left entirely to conjecture. It is obvious the Poles of the world must undergo some remarkable alterations of temperature, between the periods when the Sun, constantly shining on one of them, sinks below its horizon, to shed a lustre on the other. In the present state of our knowledge, we can only approximate to the temperature of the Pole, by availing ourselves of the observations of those who have so intrepidly navigated the icy seas of the North.

Mr. Scoresby's observations.

(200.) Previous to the publication of Scoresby's *Account of the Arctic Regions*, the North Polar temperature had been universally assumed by Meteorologists, at 30°, 31°, or 32° of Fahrenheit; and it was that active, ingenious, and enterprising man, who first ventured to place the temperature of the North Pole below the quantity that had been commonly assigned to it. The mean temperatures of the parallels of 76° 45′ and 78° North, were deduced by Mr. Scoresby from a series of 650 observations, made by himself in nine successive years. In the former latitude he found the mean temperature to be 18°.86, and in the latter 16°.99, whereas the temperatures usually assigned to these latitudes by the formula of Mayer, then commonly employed by Meteorologists, differed from the former observation nearly 16°, and from the latter more than 17°. The difference between the actual temperatures, and those estimated by the empirical formula, Mr. Scoresby attributed to the frigorific influence of the ice; and having found what this anomaly amounted to at the Pole, he subtracted it from Mayer's Polar temperature, to obtain the real temperature of the Pole, which he thus found to be 10°. But this result, Dr. Brewster remarks, is obviously too great; for since Mayer's formula errs much in excess, in those parallels where there is no accumulated ice to produce an anomaly, it must give at least an equal error in excess, for the parallel of 76° 45′. Now this error in the latitudes of 63° and 65° in Lapland is 8°; and therefore calling it also 8°, which is far too low for the latitude of 76° 45′, we have for the mean temperature, uninfluenced by the ice, 33°.8 − 8°.0 = 25°.8; from which subtracting the Polar anomaly of 21°, as computed by Mr. Scoresby, we obtain 4°.8 for the mean temperature of the Pole.

Dr. Brewster's remarks on them.

Mean temperature of the Pole influenced by the meridian on which it is approached.

(201.) Later inquiries, however, have shown, that in attempting to calculate the temperature of the Pole, a considerable alteration will take place, whether we endeavour to approach the Pole on a meridian of the Old World, or one of the New. In the Old Continent, for example, the mean heat in the parallel of 60° is 40°, whereas in the same latitude in the New World, we shall encounter a cold of 24°; and in the parallel of 78°, the second latitude adopted by Mr. Scoresby, this cold will have increased to 4°. If then we deduct for the frigorific influence of the ice, says Dr. Brewster, according to Mr. Scoresby's ingenious process, we shall find the Polar temperature to be many degrees below the *zero* of Fahrenheit's scale. Or to state the argument more popularly, since the cold at the Pole is 10°, as inferred from observations made in the *mildest* meridian, it must fall greatly below this, and even *below zero*, if inferred from observations made in the *coldest* meridian. The winds which blow from the continent of Greenland, from the Northern extremities of America, and from the frozen coast of Siberia, must produce at the North Pole an influence scarcely to be felt in the Spitzbergen seas. Dr. Brewster proves from the observations made in the second voyage of Captain Parry, that the temperature of the North Pole must be less than − 3° of Fahrenheit.

New views of Dr. Brewster.

(202.) But Dr. Brewster has communicated quite a new aspect to this interesting inquiry, in his Paper on the mean temperature of the globe published in the *Edinburgh Transactions*, by comparing the observations made by Parry in his voyage of 1819, 1820 with those deduced by Scoresby in the Spitzbergen seas. By means of 4300 observations made in the parallel of 74° 45′, and in the meridian of 110° West, Captain Parry found the mean temperature to be so low as 1°.33, whereas, as we have before remarked, Mr. Scoresby found the temperature in the latitude of 78° to amount to 16°.99. A comparison of these observations indicates a very singular state of the Isothermal lines at the Pole itself. The thermometric curve of 17°, which rises in the meridian of Spitzbergen to 78° of North latitude, descends in the meridian of Melville Island to 65°; and unless we imagine the climate of those regions to be subject to no law, we are forced to conclude that the Geographical Pole of the globe is not the coldest point of the Arctic hemisphere; and that there are *two points of greatest cold* not many degrees from the Pole, and in meridians nearly at right angles to that which passes through the West of Europe.

Two points of greatest cold.

Their probable positions.

(203.) Observations are still wanting to determine the exact positions of the Isothermal Poles; but they appear to be situated in about 80° of North latitude, and in 95° of East, and 100° of West longitude; the Transatlantic one being nearly 5° to the North of Graham Moore's Bay in the Polar Sea; and the Asiatic one to the North of the Bay of Taimura, near the North East Cape.

Further approximation to one of the Poles of maximum cold.

(204.) By combining the results of Dr. Richardson with the observations made by Parry in his second voyage, Dr. Brewster finds the Pole of maximum cold to lie within a quadrilateral figure, formed by joining the four points of observation, *viz.* Fort Enterprise, Melville Island, Igloolik, and Winter Island. Observations, however, continued for many years, on more distant Isothermal lines, will be necessary to give the accurate position of the Pole of maximum cold; while observations made near the Pole itself are extremely valuable in fixing its probable temperature.

These Poles are not limited to the same temperature.

(205.) But we are by no means confined to the supposition that these Isothermal Poles are limited to the same temperature, or confined to nearly opposite meridians; and Brewster imagines, that we may obtain even a better expression of the temperatures, by placing the Poles at different distances from the Equator, and ascribing to them different intensities of cold. The existence of a cold and a warm meridian, is a proof that there are causes which powerfully influence the mean temperature of the year, independently of the position of the Earth's axis with respect to the Sun; so that the effects which they produce can have no symmetrical relation to the Pole either in position or intensity.

Formulæ of Temperature.

General remarks on formulæ of temperature.

(206.) No greater contrast, it may be remarked, can well be exhibited than the beautiful uniformity of the celestial movements, and the capricious and ever-changing character that distinguishes the atmosphere of the Earth; and it is therefore somewhat remarkable, that the attempt to discover some law or connection among the anomalous Meteorological results, should have been made by a man distinguished for his splendid researches in the heavens, and for his successful attempt to reform and improve the lunar tables. From an allusion made in a preceding division of this Essay, our readers are prepared to anticipate the name of Mayer; and occupied as he was in the difficult task of unravelling the intricate problems connected with the movements of the Moon, and of endeavouring to trace uniformity and order in the midst of changes more considerable and capricious than distinguish any other body of our system, it was natural that the energies of such a mind, being directed to Meteorological registers, should produce some important and beneficial change.

Inquiries of Mayer.

His method analogous to that pursued by Astronomers

(207.) The method adopted by this eminent man is analogous to that which Astronomers in general have pursued with so much certainty and success, when they correct by small steps the mean place of a planet, by means of the inequalities of its motion. It does not, as Humboldt has remarked, present the result of the solar action disengaged from the influence of foreign circumstances; but estimates, on the contrary, the temperatures such as they are distributed over the surface of the globe, whatever be the cause of that distribution; and hence the object was, by having the mean heat of two places situated under different parallels of latitude, to discover by the aid of a convenient formula the temperature of every other parallel.

Difficulty of the undertaking at the time Mayer wrote.

(208.) To accomplish this at the time when Mayer wrote was a question of no ordinary difficulty. The mean temperature of the Equator, which forms so important an element of the inquiry, could only be arrived at by a rude sort of an approximation; nor were the mean temperatures of three points on the Earth's surface at that time accurately known. The materials for the creation of his formula were only to be found, with any tolerable accuracy, between the parallels of 40° and 50° of North latitude; and from a diligent examination of these, he imagined that the temperature at the surface of the Earth varied as the square of the sine of the latitude. His formula was exhibited under the form of

$$T = 84 - 52 \sin^2 L,$$

which by a ready transformation by the arithmetic of sines, becomes

$$T = 58 + 26 \cos 2 L.$$

Mayer regarded the Equatorial temperatu as 84°.

(209.) By allowing the latitude to vary in the first of these formulæ, we shall perceive that Mayer regarded 84° as the mean Equatorial temperature, since when the latitude is zero, $\sin^2 L$ vanishes, and the value of T becomes that quantity. On the other hand, he estimated the temperature of the Pole at 32°, because when the latitude is 90°, $\sin^2 L$ being radius, the value of T must become that of the freezing point.

The temperature c the parall of 45° as 58°.

(210.) In the second formula, the mean temperature of the parallel of 45° was estimated at 58°, and the coefficient 26° was regarded as the difference between the last-mentioned temperature and that of freezing water at the Pole.

If these formulæ be adapted to Reaumur's scale, we shall have

$$T = 24 \cos^2 L,$$

which, by the arithmetic of sines, becomes

$$T = 12 + 12 \cos 2 L.$$

Labours Kirwan.

(211.) Kirwan, who adopted the views of Mayer, gave an example by which he deduced the constant coefficient of the formula, as well as the Equatorial temperature. Thus regarding the elements referred to as indeterminate quantities, the formula may be exhibited under the form of

$$T = \alpha - \beta \sin^2 L;$$

and taking the temperatures of the parallels of 40° and 50° at 62°.1 and 52°.9, we shall obtain the equations

$$\alpha - \beta \sin^2 40° = 62°.1,$$

and

$$\alpha - \beta \sin^2 50° = 52°.9.$$

These equations reduced will give for α the Equatorial temperature 84° nearly, and for the coefficient β 53° nearly. Hence the temperature of the Pole must be regarded as 31°.

Playfair's Geometrical illustration of Mayer's formula.

(212.) Playfair, by adopting Mayer's formula under the form

$$T = 58 + 26 \cos 2 L,$$

above deduced, furnishes a neat Geometrical construction for determining the mean temperature. In any line graduated into equal parts to represent the divisions of the Thermometric scale, (fig. 1. plate 1. METEOROLOGY,) take A C = 84, the mean Equatorial temperature, (according to Mayer,) and A B = 58, which in the formula indicates the mean temperature of the parallel of 45°. From B, as a centre, let a semicircle be described with the radius B C equivalent to 26, the coefficient of the last term of the formula. Take the arch C G equal to the double latitude of any parallel; and from G draw G O at right angles to A C, then will A O represent the mean temperature of that parallel, according to the scale of Fahrenheit.

Lichtenberg's application of Mayer's formula.

(213.) M. Lichtenberg, the Editor of Mayer's posthumous Works, applied this formula to thirteen observations of mean temperature made between the Cape of Good Hope and Stockholm; and their agreement was considered at that time to be remarkable.

Formula of Daubuisson.

(214.) In the year 1819, M. Daubuisson, in his *Traité de Géognosie*, resumed the subject of the Earth's temperature, and gave the formula

$$T = 27° \cos^2 L$$

for finding the mean temperature according to the centigrade scale. This formula is superior in accuracy to Mayer's; but M. Daubuisson considers it as applicable principally between the parallels of 30° and 60° North latitude. The coefficient 27° is regarded by the author of the formula as the mean temperature of the Equator, in order to make the results agree with observations made in the temperate regions, whereas the mean temperature of the Equator, as ascertained by Humboldt, is 27°.5.

Brewster's comparison of Mayer's formula with the observations of Humboldt.

(215.) Among other advantages resulting from the publication of Humboldt's Memoir on Isothermal lines, was Dr. Brewster's comparison of Mayer's formula with the observations collected by that distinguished traveller. Brewster found by comparing the temperature of the Equator with that of the parallel of 45°, and also with that of the highest latitude in Humboldt's series, that the cold increased much more rapidly towards the Poles than had been believed; and upon extending the comparison to the intermediate temperatures, he found the mean heat of any place to be well represented by the radius of its parallel of latitude; or, in other words, that the temperature varies as the cosine of the latitude. By adopting 81°.5 for the mean temperature of the Equator, Brewster's formula therefore assumed the form of

$$T = 81°.5 \cos L \ldots\ldots (F),$$

Brewster's formula.

and which will be found to agree exceedingly well with observations made at the following places; the positive and negative errors approaching very nearly to an equilibrium.

TABLE XXIX.—*Of Mean Temperatures.*

Names of Places.	Latitude.	Observed Mean Temperature.	Mean Temperature calculated by Brewster's formula.	Difference.
Equator	0° 0′	81°.50	81°.50	0°.00
Columbo	6 58	79.50	80.90	1.40+
Chandernagore	22 52	75.56	75.10	0.46−
Cairo	30 2	72.82	70.56	1.76−
Funchal	32 37	68.54	68.62	0.08+
Rome	41 54	60.44	60.66	0.22+
Montpellier	43 36	59.36	59.03	0.33−
Bourdeaux	44 50	56.48	57.82	1.34+
Milan	45 28	57.18	58.28	1.10+
Nantes	47 13	54.68	55.35	0.67+
St. Malo	48 39	54.14	53.85	0.29−
Paris	48 50	51.89	53.65	1.76+
Brussels	50 50	51.80	51.47	0.33−
Dunkirk	51 20	50.54	51.25	0.71+
London	51 30	50.36	50.74	0.38+
Bushey Heath	51 37¾	51.20	50.58	0.62−
Kendal	54 17	46.02	47.58	1.56+
New Malton	54 10	48.28	47.53	0.75−
Lyndon	54 34	48.90	49.37	0.47+
Dublin	53 21	49.10	48.65	0.45−
Copenhagen	55 41	45.68	45.95	0.27+
Edinburgh	55 57	46.23	45.64	0.59−
Carlscrona	56 16	46.04	45.46	0.58−
Fawside	56 58	44.30	44.26	0.04−
Kinfauns	56 23½	46.20	45.12	1.08−
Stockholm	59 20	42.26	41.57	0.69−
Upsal	59 51	42.08	40.94	1.14−
Abo	60 27	40.00	40.28	0.28+
Umeo	63 50	33.08	35.96	2.88+
Uleo	65 30	33.26	34.38	1.11+

Comparison of the temperature of different meridians.

(216.) Reasoning on general principles, we should first imagine that the distribution of heat over the meridians of the New World, would coincide with observations made in the Old World; but as the condition of more distant climates was better known, the severity of a Canadian and a Siberian winter became proverbial. Humboldt has shown, that though the temperature of the Equatorial regions is nearly the same under all meridians, yet in higher latitudes it declines rapidly in the New World, and also under the Eastern meridians of Asia. According to this view, it would seem as if some correction were necessary for longitude, and that the latitude is not the only Geographical element that requires consideration. The subject, however, must be approached with extreme caution, on account of the limited number of observations that have been made in the regions referred to; and Dr. Brewster has hence contented himself with the following modification of his first formula, to denote the temperature of the New World,

$$T = 81°.5 \cos^2 L \times 1°.13.$$

Modification of Brewster's formula.

This formula makes the Equatorial and Polar temperatures of the New World coincide with those of the Old World, while in intermediate latitudes, the calculated and observed results do not differ, upon an average, so much as 1°, as may be seen by a reference to the columns of the succeeding Table.

TABLE XXX.

Latitude.	Temperature of Old World.	Temperature of New World.	Difference between Old and New World.	Temperature of New World calculated by the formula.	Difference between Observation and Calculation.
30°	70°.52	6[illegible]°.92	3°.60	69°.07	+2°.15
40	63.14	54.50	8.64	54.04	−0.46
50	50.90	37.94	12.96	38.06	+0.12
60	40.64	23.72	16.92	23.02	−0.70

Two points of maximum cold.

(217.) In following up this interesting inquiry, Dr. Brewster was led to imagine, as we have before remarked, the existence of two points of maximum cold within the frigid zone as extremely probable, and deduced a formula of mean temperature according to such a supposition. The gradation of heat on the Transatlantic meridian is so essentially different from that in the West of Europe, that it is impossible to represent the two classes of phenomena by a single formula, in which the limiting temperatures are to be found at the Equator and the Pole. Such, indeed, are the anomalies existing in the distribution of heat in the Polar latitudes, that observation alone must determine the form of the Isothermal lines. Dr. Brewster endeavoured to trace their resemblance to the Isochromatic curves, and to calculate the temperatures by the product of the sines of the distance of the place from the two Isothermal Poles; but he found, after much laborious inquiry, that this law did not accurately represent the facts, and that they might be more accurately represented by the formula

Formulæ relating to the Pole of maximum cold.

$$\text{Mean temp.} = 82°.8 \sin D;$$

upon the supposition that the greatest cold is 0° of Fahrenheit, or

$$\text{Mean temp.} = 86°.3 \sin D - 3\tfrac{1}{2}°,$$

upon the supposition that the maximum degree of cold is $-3\frac{1}{2}°$ of Fahrenheit, 82°.8 being the mean temperature of the Equator in the warmest meridian, and D the distance of the place nearest the Isothermal Pole.

Application of the formulæ.

(218.) To bring these formulæ to the severest possible test, Dr. Brewster contrasted them with observations made in intermediate meridians, both in the Old and the New World. In this comparison he began with the Asiatic Pole, supposing it to have a temperature of $-3\frac{1}{2}°$, and to be placed in 80° North latitude, and 95° East longitude; and by employing the formula before given

$$\text{Mean temp.} = 86°.3 \sin D - 3\tfrac{1}{2}°,$$

Erroneous assumption.

he found that the observed temperature exceeded the temperature calculated by the formula, in eleven cases out of thirteen; from which he very properly inferred that he had assumed too great a degree of cold for the Asiatic Pole. By assuming the temperature of this Pole at zero of Fahrenheit, as supposed in the formula

$$\text{Mean temp.} = 82°.8 \sin D,$$

Corrections of the formulæ.

he found that the differences between the observed and calculated temperatures of the same thirteen places, were far within the limits of the errors of observation; but that being negative in general, a more correct approximation might be found by supposing the Asiatic Pole to have a temperature of 1° Fahrenheit, which is $4\frac{1}{2}°$ warmer than the Transatlantic Pole. The last formula in this case became, therefore, transformed into

$$\text{Mean temp.} = 81°.8 \sin D + 1° \ldots. (G)$$

which, applied to the thirteen places before alluded to, gave the following results:

TABLE XXXI.

Names of Places.	Distance from Asiatic Pole.	Mean Temperature Observed.	Mean Temperature Calculated.	Difference.
Enontekies.......	20° 39′	31°.03	29°.85	−1°.18
Uleo.............	23 16	33.08	33.31	+0.23
Umeo............	25 06	33.26	35.70	+2.44
St. Petersburgh....	27 11	38.84	38.37	−0.47
Stockholm	29 44	42.30	41.57	−0.73
Moscow	29 55	43.16	41.80	−1.36
Warsaw	36 06	48.56	49.20	+0.64
Astracan.........	37 25	49.08	50.70	+1.62
Vienna	40 37	51.76	54.25	+2.49
Pekin............	40 56	54.86	54.59	−0.27
Nangasaki	48 57	60.80	62.69	+1.89
Seringapatam.....	68 04	77.00	76.92	−0.08
Columbo	73 12	79.50	79.33	−0.17

Application of the theory to observations made round the Transatlantic Pole

(219.) A comparison of theory with observations made round the Transatlantic Pole, affords results equally satisfactory. In this case Dr. Brewster had recourse to the formula

$$\text{Mean temp.} = 86°.3 \sin D - 3\tfrac{1}{2}° \ldots. (H),$$

the Pole being supposed to be situated in 80° North latitude, and 100° West longitude, and to have a temperature of $-3\frac{1}{2}°$.

TABLE XXXII.

Names of Places.	Distance from the American Pole.	Mean Temperature Observed.	Mean Temperature Calculated.	Difference.
Melville Island....	5° 15′	1°.33	4°.39	+3°.06
Upernavick.......	12 15	16.34	14.81	−1.53
Omenak.........	13 58	16.60	17.33	+0.42
Godhavn.........	17 08	22.04	21.92	−0.12
Godthaab........	20 19	26.07	26.46	+0.39
Fort Churchill	20 58	25.34	27.38	+2.04
Julianeshaab	24 25	30.33	32.17	+1.84
Eyafiord..........	24 08	32.16	31.78	−0.38
Nain.............	25 16	30.03	33.34	+3.31
Okkak	24 47	31.00	32.68	+1.68
Quebec..........	34 44	41.90	45.67	+3.77
Cambridge	39 04	50.36	50.89	+0.53
New York	39 53	53.78	51.84	−1.94
Philadelphia......	41 08	53.42	53.27	−0.15
Williamsburg.....	43 40	58.10	56.09	−2.01
Orotava	60 00	70.11	71.24	+1.13
Equat. W. lon. 100°	80 00	81.50	81.50	0.00
Equat. E. lon. 95°			81.56	+0.06

Position o the Easter Pole of ma imum col in the Sout ern hemi- sphere.

(220.) By comparing the mean temperature of Van Diemen's Land with that of the Cape of Good Hope, as ascertained by many accurate observations reduced by Mr. Colebrooke, we obtain a position for the Eastern Pole of maximum cold in the Southern hemisphere, corresponding with the position of the opposite Pole in the Northern hemisphere. In order to determine this point, Dr. Brewster computed the mean temperature of Hobart Town, by supposing the Poles of maximum cold to have the same position in the Southern as they have in the Northern hemisphere. If we suppose the Pole nearest to Hobart Town to have the same degree of cold as the American Pole, then the mean temperature of Hobart Town will be 53°.11, differing little more than half a degree from the observed mean temperature; and if we suppose it to be the same as the Asiatic Pole, the mean temperature will be 54°.67, differing 2° from observation. It deserves to be remarked, however, that *both* these computed results *lie between* the mean temperature actually observed at Hobart Town and Macquarie Harbour.

Mr. Atkinson's comparative Tables of the different formulæ.

(221.) Having reviewed the different formulæ that have been presented for the purpose of finding the mean temperature of a place, we shall add the following comparative Tables of their application; for which we are indebted to Mr. Atkinson's excellent Paper before quoted. The places selected are all situated nearly at the level of the sea.

TABLE XXXIII.

Names of Places.	Observed Mean Temperature of Place.	No. of Years' Observations.	Brewster's formulæ. 1st. Calculated Temperature.	Brewster's formulæ. 1st. Error.	Brewster's formulæ. 2nd. Calculated Temperature.	Brewster's formulæ. 2nd. Error.	Mayer's. Calculated Temperature.	Mayer's. Error.	Daubuisson's. Calculated Temperature.	Daubuisson's. Error.
	Fahr.		Fahr.		Fahr.		Fahr.		Fahr.	
London	50°.36	..	50°.74	+0°.38	54°.05	+3°.69	52°.93	+2°.57	50°.83	+0°.47
Dunkirk	50.54	7	51.25	+0.71	54.11	+3.57	53.36	+2.82	51.22	+0.68
Amsterdam	51.62	5	49.76	−1.86	52.22	+0.60	52.13	+0.51	50.12	−1.50
Brussels	51.80	13	51.47	−0.33	53.94	+2.14	53.54	+1.74	51.39	−0.41
Francker	51.26	11	49.50	−1.76	51.70	+0.46	51.92	+0.66	49.93	−1.33
St. Malo	54.14	3	53.84	−0.30	57.32	+3.18	55.57	+1.43	53.21	−0.93
Nantes	54.68	6	55.36	+0.68	58.66	+3.98	56.91	+2.23	54.42	−0.26
Bourdeaux	56.48	10	57.80	+1.32	60.81	+4.33	59.16	+2.68	56.44	−0.04
Marseilles	59.00	7	59.33	+0.33	61.28	+2.28	60.62	+1.62	57.76	−1.24
Montpellier	59.36	10	59.02	−0.34	61.23	+1.87	60.32	+0.96	57.49	−1.87
Mean Errors				−0.12		+2.61		+1.72		−0.64

Errors of the several formulæ.

(222.) From this Table, it appears that Brewster's first formula gives the temperature *too low* by 0°.12, and the second *too high* by 2°.61. Mayer's formula is *too high* by 1°.72, and Daubuisson's *too low* by 0°.64, at the level of the sea. These differences Mr. Atkinson denominates *corrections* for the level of the sea.

Application of the same formulæ to places situated above the level of the sea.

(223.) The same formulæ may also be compared by means of places situated *above* the level of the Ocean, and thus some notion be formed of their comparative accuracy; and Mr. Atkinson has prepared the following Table to illustrate this view of the subject.

TABLE XXXIV.

Names of Places.	Heights.	Observed Mean Temperature of the Year.	No. of Years' Observations.	Brewster's formulæ. 1st. Calculated Temperature.	Brewster's formulæ. 1st. Error.	Brewster's formulæ. 2nd. Calculated Temperature.	Brewster's formulæ. 2nd. Error.	Mayer's. Calculated Temperature.	Mayer's. Error.	Daubuisson's. Calculated Temperature.	Daubuisson's. Error.
	Feet.	Fahr.		Fahr.		Fahr.		Fahr.		Fahr.	
Montmorency	498	50°.74	33	53°.49	+2°.75	56°.21	+5°.47	55°.26	+4°.52	52°.93	+2°.19
Paris*	222	51.08	11	53.65	+2.57	56.37	+5.29	55.40	+4.32	53.06	+1.98
Strasburg	480	49.28	..	53.93	+4.65	55.65	+6.37	55.65	+6.37	53.28	+4.00
Manheim*	432	50.18	7	52.95	+2.77	54.59	+4.41	54.79	+4.61	52.51	+2.33
Vienna*	420	50.54	..	54.32	+3.78	54.47	+3.93	55.99	+5.45	53.59	+3.05
Buda*	494	51.08	..	55.08	+4.00	54.70	+3.62	56.66	+5.58	54.20	+3.12
Milan	390	55.76	24	57.16	+1.40	58.54	+2.78	58.56	+2.80	55.90	+0.14
Gottingen	456	46.94	..	50.70	+3.76	52.14	+5.20	52.90	+5.96	50.81	+3.87
Means	424				+3.21		+4.63		+4.95		+2.58

* The heights of these four places are derived from the *Edinburgh Philosophical Journal*, vol. v. p. 32.

Errors of the several formulæ.

(224.) Hence it appears, that at the mean elevation of 424 feet, Brewster's first formula makes the temperature *too high* by 3°.21, and his second by 4°.63. Mayer's also gives it too high by 4°.95, and Daubuisson's by 2°.58. These numbers being the *corrections* to be applied when the temperature of a place is required 424 feet above the level of the sea.

Remarks relative to the preceding Tables.

(225.) As the places in Table XXXIV., with the exception of Montmorency and Paris, lie further to the East than those in Table XXXIII., it is manifest that the results obtained by employing the corrections deduced from the latter Table will not be the same as those obtained by adopting the former; for Humboldt, as we have before remarked, has shown, that temperature varies with the longitude as well as the latitude, only in a much less degree. If, therefore, the given place be situated in the Western regions of Europe, or near the primary meridian, the corrections in Table XXXIII. are to be preferred; but if it lie in about 15° or 20° of East longitude, the corrections in Table XXXIV.; and if it be situated in a region about the middle between these, the corrections in both Tables should be employed, and the mean of the whole taken.

Attempt to estimate the temperature of a given place by supposing the ground taken away from beneath it.

(226.) Hence, says Mr. Atkinson, if we wish to know what the temperature would be directly below a given place, supposing the ground taken away from beneath it to a great extent, we have only to calculate its temperature by each of the above four formulæ. Then if the *first* set of corrections be applied to the calculated temperatures, each to each, the four results would be the temperature, as deduced from the formulæ respectively, on the supposition that the ground was removed from under the place, *down to the level of the sea.* But, if the second set of corrections had been applied, the mean of the results would be the temperature of a point, directly below the place, but 424 feet above the level of the sea. And if the mean temperature of the place itself had been accurately observed, the difference between the *observed* and *calculated* temperatures would be *the change of temperature due to the whole height*, if the first set of corrections had been employed; but if the *second* set of corrections had been adopted, the *difference* would be the *alteration of temperature* due to the *height diminished* by 424 feet.

Differences between the calculated temperatures of certain places, and their observed temperatures.

(227.) The next Table exhibits the *differences* between the temperatures of the eleven places mentioned in it, calculated as directed above, and the *observed* mean temperatures of the same places. From what has been already mentioned respecting the apparent connection between the longitude and the mean temperature, it might be expected that the differences as deduced from the corrections in Table XXXIII. would give different results from those deduced from the corrections in Table XXXIV., and accordingly Mr. Atkinson found it to be so. But as the eleven places adopted in the succeeding Table occupy nearly the central parts of that portion of Europe in which the eighteen places in Tables XXXIII. and XXXIV are situated, it seems highly probable that the mean of the whole will be a tolerable approximation to the truth.

TABLE XXXV.

Names of Places.	Heights in Feet.	Observed Mean Temperature.	No. of Years' Observations	Difference between the Temperature at the Level of the Sea and the Observed Temperature. The 1st Set of Corrections is used here.				Difference between the Temperature at the Height of 424 Feet, and the Mean Observed Temperature of each Place. The 2nd Set of Corrections is used here.				
				Brewster's 1st formula.	Brewster's 2nd formula.	Mayer's formula.	Daubuisson's formula.	Heights diminished by 424 feet.	Brewster's 1st formula.	Brewster's 2nd formula.	Mayer's formula.	Daubuisson's formula.
		Fahr.		Fahr.	Fahr.	Fahr.	Fahr.	Feet.	Fahr.	Fahr.	Fahr.	Fahr.
Convent of Pys-senburg*	3264	42°.98	6	11°.96	10°.36	11°.58	11°.60	2840	8°.57	8°.34	8°.35	8°.38
Chamouni*	3372	39.20	..	17.52	16.68	17.12	16.88	2948	14.19	14.66	13.89	13.66
Zarich†	1393½	47.84	6	7.48	6.29	7.21	7.09	969½	4.15	4.27	3.98	3.87
Coire†	1933½	48.92	4	6.96	5.57	6.63	6.47	1509½	3.63	3.55	3.40	3.25
Munich†	1659½	50.74	..	3.77	2.14	3.59	3.55	1285½	0.44	0.12	0.36	0.33
Ratisbon	1104	47.66	..	6.00	4.23	5.92	5.95	680	2.67	2.21	2.69	2.73
Berne†	1702½	49.28	..	7.37	6.33	6.98	6.74	1278½	4.04	4.31	3.75	3.52
Geneva*	1177	49.64	7	7.25	6.45	6.51	6.28	753	3.92	4.43	3.28	3.06
Clermont	1260	50.00	7	6.97	6.70	6.56	6.29	836	3.64	4.68	3.33	3.07
Dijon	810	50.90	..	4.47	3.90	4.20	4.08	386	1.14	1.88	0.97	0.86
Besancon	804	51.26	..	4.18	3.44	3.92	3.79	380	0.85	1.42	0.69	0.57
	18480			83.87	72.09	80.22	78.72	13816	47.24	49.87	44.69	43.30

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* The heights of these three places are taken from the *Edinburgh Philosophical Journal*, vol. iv. p. 276.

† The heights of these four places, as given above, are obtained by taking a mean between the heights adopted in the note at p. 275, vol. iv., and those given in the Table and its notes, p. 32—39, vol. v. of the same Journal. There is, probably, a mistake in the observed mean temperature of Munich. Had it been rejected, the mean result of the whole would have been a little different from the above, but varying still more from the quantity generally adopted by Philosophers. It may serve, however, as an example, to show how necessary it is to employ a great number of places in investigations of this kind, particularly where the altitude is not great. When the height is considerable, a small error in the mean temperature makes a less difference.

Mean temperature of year deduced from a single month.

(228.) It is useful sometimes to be able to approximate to the mean temperature of the year, by the aid of observations made during a particular part of it; and accordingly some have been made to discover the month which approaches the nearest to it. Kirwan supposed that the mean temperature of April approached the nearest to that of the year, but Humboldt conceives it to be October. In the next Table, some comparative results are afforded of the two months.

Table XXXVI.

Names of Places.	Mean Temperature.			Names of Places.	Mean Temperature.		
	Of the Year.	Of October.	Of April.		Of the Year.	Of October.	Of April.
Cairo	72°.3	72°.3	77°.9	Gottingen	46°.9	47°.1	44°.4
Algiers	69.8	72.1	62.6	Franeker	52.3	54.9	50.0
Natchez	65.0	68.4	66.4	Copenhagen	45.7	48.7	41.0
Rome	60.4	62.1	55.4	Stockholm	42.3	42.4	38.5
Milan	55.8	58.1	55.6	Christiana	42.6	39.2	42.6
Cincinnati	53.6	54.9	56.8	Upsal	41.7	43.3	39.7
Philadelphia	53.4	54.0	53.6	Quebec	41.9	42.8	39.6
New York	53.8	54.5	49.1	Petersburgh	38.8	39.0	37.0
Pekin	54.7	55.4	57.0	Abo	41.4	40.0	40.8
Buda	51.1	52.3	49.1	Drontheim	39.9	39.2	34.3
London	51.8	52.3	49.8	Uleo	33.1	37.9	34.2
Paris	51.1	51.3	48.2	Umeo	33.3	37.8	34.0
Geneva	49.3	49.3	45.7	North Cape	32.0	32.0	30.2
Dublin	48.6	48.7	45.3	Enontekies	27.0	27.5	26.6
Edinburgh	47.8	48.2	46.9	Nain	26.4	33.1	27.5

Playfair's formula for ascertaining the mean temperature of any day.

(229.) Playfair, following the steps of Kirwan, adopted the temperature of the latter end of April as the mean temperature of the year, and endeavoured to create a formula which should enable him to approximate to the mean temperature of any day. This formula is the following

$$y = \mathrm{T} + \mathrm{F} \sin (\lambda - 30) \ldots . (\mathrm{I}),$$

in which T denotes the mean temperature of the given place, F a constant coefficient determined by observation, λ the mean longitude of the sun computed from the first of Aries, for any day of the year, the mean temperature of which is y.

(230.) That the mean temperature of the latter end of April is however nearly that of the year, may be seen by the following admirable series of observations, made in the Observatory of the Academy of Sciences at Stockholm, during a period of fifty years, and embracing no less than 54,750 observations. An excellent account of it will be found in Kongl. Vetenskap's *Academiens nya Handlingar*, tom. xxix. p. 294, for 1808, or the *Annals of Philosophy* for 1813, vol. i. From these observations, it appears that the mean temperature of the place of observation, from 54,750 observations, is 5¾°, or 5°.765 above the freezing point of the thermometer of Celsius, or 42°.377 Fahrenheit. The year has been divided by M. Ofverbom, the author of the abstracts of the observations, into 73 *penthemerons*, or periods of five days each, with some little anomaly for the intercalary days; and we have added the whole series, in order that our readers may be able not only to judge of the mean temperature of April, but also of the other months of the year.

Observations made at Stockholm to determine the mean temperature of the different months of the year.

Table XXXVII.

Number of Penthemerons.	Middle Day of the Penthemerons.		Medium of 50 Years' Observations.	Probable Mean Temperature.	Difference.	The third column expressed in degrees of Fahrenheit.
1	Jan.	3	− 5°.596	− 4°.521	−1°.075	21°.927
2		8	− 5.098	− 4.898	−0.200	22.824
3		13	− 4.791	− 5.214	+0.423	23.376
4		18	− 4.215	− 5.456	+1.241	24.413
5		23	− 4.193	− 5.572	+1.371	24.453
6		28	− 3.401	− 5.421	+2.020	25.878
7	Feb.	2	− 3.942	− 5.165	+1.223	24.904
8		7	− 4.731	− 4.838	+0.107	23.484
9		12	− 4.690	− 4.451	−0.239	23.558
10		17	− 3.683	− 4.018	+0.331	25.403
11		22	− 2.995	− 3.532	+0.537	26.609
12		27	− 2.685	− 3.008	+0.323	27.167
13	March	4	− 3.229	− 2.446	−0.783	26.188
14		9	− 3.660	− 1.848	−1.812	25.410
15		14	− 2.272	− 1.216	−1.056	27.910
16		19	− 2.190	− 0.552	−1.638	28.060
17		24	− 1.168	+ 0.143	−1.311	29.898
18		29	− 0.281	+ 0.867	−1.148	31.494
19	April	3	+ 1.273	+ 1.620	−0.347	34.295
20		8	+ 2.470	+ 2.399	+0.071	36.446
21		13	+ 3.009	+ 3.205	−0.196	37.416
22		18	+ 3.776	+ 4.037	−0.261	38.797
23		23	+ 4.926	+ 4.893	+0.033	40.867
24		28	+ 5.773	+ 5.775	−0.002	42.391
25	May	3	+ 6.572	+ 6.828	−0.256	43.830
26		8	+ 7.502	+ 7.849	−0.347	45.504
27		13	+ 8.279	+ 8.838	−0.559	46.902
28		18	+10.136	+ 9.793	+0.343	50.245
29		23	+10.888	+10.713	+0.175	51.598
30		28	+11.446	+11.597	−0.151	52.603
31	June	2	+13.026	+12.442	+0.548	55.447
32		7	+13.978	+13.248	+0.730	57.160
33		12	+14.442	+14.013	+0.429	57.996
34		17	+15.237	+14.733	+0.504	59.427
35		22	+15.423	+15.406	+0.017	59.761
36		27	+16.089	+16.028	+0.061	60.960
37	July	2	+16.572	+16.596	−0.024	61.830
38		7	+17.272	+17.102	+0.170	63.089
39		12	+17.556	+17.538	+0.028	63.619
40		17	+17.839	+17.892	−0.053	64.110
41		22	+18.068	+18.133	−0.069	64.515
42		27	+18.180	+18.103	+0.077	64.720
43	Aug.	1	+17.856	+17.838	+0.018	64.141
44		6	+17.449	+17.470	−0.021	63.408
45		11	+17.211	+17.020	+0.191	62.898
46		16	+16.446	+16.503	−0.057	61.603
47		21	+16.197	+15.926	+0.271	61.155
48		26	+15.094	+15.295	−0.201	59.169
49		31	+14.326	+14.614	−0.288	57.787
50	Sept.	5	+13.734	+13.886	−0.152	56.721
51		10	+12.924	+13.114	−0.190	55.263
52		15	+11.993	+12.301	−0.308	53.587
53		20	+11.132	+11.449	−0.317	52.038
54		25	+10.459	+10.559	−0.100	50.826
55		30	+ 8.998	+ 9.633	−0.635	48.196
56	Oct.	5	+ 8.785	+ 8.672	+0.113	47.613
57		10	+ 7.513	+ 7.678	−0.165	45.523
58		15	+ 6.612	+ 6.651	−0.039	43.901
59		20	+ 5.604	+ 5.618	−0.014	42.087
60		25	+ 5.251	+ 4.746	+0.505	41.452
61		30	+ 4.177	+ 3.894	+0.283	39.512
62	Nov.	4	+ 3.787	+ 3.067	+0.720	38.817
63		9	+ 3.155	+ 2.265	+0.890	37.679
64		14	+ 1.872	+ 1.490	+0.382	35.369
65		19	+ 0.176	+ 0.742	−0.566	32.317
66		24	− 0.383	+ 0.023	−0.406	31.311
67		29	− 0.611	− 0.667	+0.056	30.900
68	Dec.	4	− 1.405	− 1.326	−0.079	29.471
69		9	− 1.602	− 1.952	+0.350	29.117
70		14	− 2.165	− 2.544	+0.379	28.103
71		19	− 3.155	− 3.100	−0.055	26.321
72		24	− 3.164	− 3.617	+0.453	26.305
73		29	− 4.334	− 4.092	−0.242	24.199
	Mean......		+ 5.765			

Uniformity of heat at any point of the globe.

(231.) It is also some argument in favour of the preceding observations, and of the advantages to be derived from the employment of formulæ of temperature, that the quantity of heat which any point of the globe receives, is much more equal during a long series of years, than we should be led at first to conceive from the uncertain testimony of our sensations, and the variable product of our harvests. In a given place, says Humboldt, the number of days during which the North-East or South-West winds blow, preserve a very constant ratio; because the direction and force of these winds, which bring warmer or colder air, depend upon general causes,—on the declination of the sun,—on the configuration of the coast,—and on the position of the neighbouring continent. It is less frequently a diminution in the mean temperature, than an extraordinary change in the division of the heat between the different months, which occasions bad harvests. M. Humboldt also states, that a careful examination of a series of good Meteorological observations, made during ten or twelve years between the parallels of 47° and 49°, proved that the *annual* temperatures varied only from 1°.8 to 2°.7; those of *winter* from 3°.6 to 5°.4, and those of the months of winter from 9° to 10°.8. The next Table illustrates the mean temperature of Geneva for twenty years.

TABLE XXXVIII.

Years.	Mean Temp.	Years.	Mean Temp.
1796	49°.3	1806	51°.4
1797	50.5	1807	49.3
1798	50.0	1808	46.9
1799	48.7	1809	48.9
1800	50.5	1810	51.1
1801	51.1	1811	51.6
1802	50.9	1812	47.8
1803	50.4	1813	48.6
1804	51.1	1814	48.2
1805	47.8	1815	50.0
Mean of 20 Years..............			49°.67

Thermometrical oscillations for Paris.

(232.) In the succeeding Table is shown the Thermometrical oscillations during eleven years at Paris, for the whole year, the winter, the summer, the coldest and warmest months, and the month which represents most accurately the mean annual temperature.

TABLE XXXIX.

Observations of M. Bouvard.	Mean Temperature.					
	Of the Year.	Of Winter.	Of Summer.	Of January.	Of August.	Of October.
Paris 1803	51°.1	36°.7	67°.6	34°.3	67°.6	50°.5
1804	52.0	41.0	65.5	43.9	64.6	52.7
1805	49.5	36.0	63.1	34.9	64.8	49.3
1806	53.4	40.6	65.3	43.0	64.6	51.8
1807	51.4	42.3	67.8	36.1	70.5	54.3
1808	50.5	36.7	66.2	36.3	66.6	48.2
1809	50.9	40.5	62.4	40.8	64.2	49.6
1810	50.9	36.5	63.3	30.6	63.7	52.9
1811	52.7	39.2	65.1	26.6	63.7	57.6
1812	49.8	39.6	63.1	34.7	64.2	51.1
1813	49.8	36.1	61.7	32.5	62.6	53.1
Mean of these 11 Years.	51.1	38.7	64.0	36.6	65.1	51.9

(233.) With reference to this Table it may be remarked, that the greatest aberration from the mean of the year, is in 1806, amounting to + 2°.3, the positive errors amounting to + 5°.1, and the negative to − 5°.2. For the winter temperature, the greatest deviation from the mean is + 3°.6, in 1807, the sum of the positive errors being + 11°.0, and of the negative − 11°.5. In like manner for the summer temperature of Paris, the maximum deviation is + 3°.2, the sum of the positive errors being + 9°.9, and of the negative − 9°.4. And if we take the corresponding years from Table XXXVIII. we shall find the maximum deviation from the mean amounting to − 2°.8, the positive errors amounting to + 8°.8, and those of a negative kind to − 7°.6. So that in two places distant, like Paris and Geneva, eighty leagues from each other, the variations seem to be very uniform in the annual temperature; and also if the succeeding Table be referred to, uniform in the seasons, although the Thermometrical quantities differ widely from each other.

Variations of annual temperature between Paris and Geneva seem very uniform.

TABLE XL.

Years.	Mean Temperature of Summer at Geneva.	Mean Temperature of Winter at Geneva.
1803	67°.6	32°.2
1804	66.2	38.3
1805	63.0	33.8
1806	64.6	38.5
1807	68.2	35.8
1808	63.5	33.8
1809	63.1	35.1

Formula for greater elevations.

(234.) But it is often useful to be able to approximate to the mean temperature of places situated at greater elevations above the sea; and, accordingly, Mr. Atkinson has furnished the formula

$$97^{\circ}.08 \cos^{\frac{3}{2}} \text{lat.} - 10^{\circ}.53 - \frac{h}{251 + \frac{h}{200}} \ldots\ldots\ldots (K)$$

for the mean temperature of a place at the elevation h.

Remarks on it. (235.) In submitting the formula, however, to the test of actual observation, the Table which he has furnished, although very copious and valuable, is confined to observations made in America, and must therefore be received with caution. At the same time also it should be remarked, that it is open to another objection, grounded as it is on the high temperature he has attempted to assign to the Equator. Still it must be admitted, that the temperatures deduced from it approach more nearly to the actual values found by observation, than could have been anticipated from the great elevations of the places computed, and the variable conditions of temperatures found in tropical valleys, and on the plateaus by which those regions are distinguished. The great range of observation from the Equator to Winter Harbour in Melville Island, embraced by the Table, is also another feature which entitles it to consideration.

TABLE XLI.

Names of Places.	Latitude.	Height.	Observed Mean Temperature.	Temperature by the formula.	Difference.	Localities.
		Feet.	Fahr.	Fahr.	Fahr.	
Limits of perpetual snow	0° 00′	15744	34°.88	37°.81	+2°.93	
Quito	0 13 S.	9538	57.92	54.95	−2.97	At the foot of Pinchincha, a narrow valley.
Llactacunga	0 55 —	9473	59.00	54.80	−4.20	Bottom of one of the valleys of Quito.
Hambato	1 14 —	8849	60.44	56.55	−3.89	Ditto.
Pasto	1 15 N.	8308	58.28	58.11	−0.17	Near the foot of a volcanic mountain.
Almaguer	1 56 —	7413	62.60	60.73	−1.87	Gentle declivity, covered with thick vegetation.'
Riobamba Nuevo	1 42 S.	9482	61.16	54.72	−6.44	Arid plains of Tupia, covered with pumice stones.
Alausi	2 12 —	7970	59.00	59.04	+0.04	
La Plata	2 24 N.	3437	74.66	73.61	−1.05	Very warm valley, joining that of L'Alto Magdalena.
Malbasa	2 28 —	9971	54.50	53.28	−1.22	Elevated plains cooled by the snows of the volcano of Puracé.
Popayan	2 29 —	5815	65.66	65.65	−0.01	Small plateau, a little above the valley of Cauca.
Plateau de los Pastos ...	2 34 —	10099	54.50	52.90	−1.60	
Cuença	2 55 S.	8633	60.08	57.01	−2.97	A valley among the higher Andes.
Neiva	3 10 N.	1702	77.00	79.77	+2.77	In the extensive valley of Magdalena.
Loxa	3 59 S.	6855	64.40	62.17	−2.23	Small plateau, in a beautiful and extensive valley.
Tocayma	4 16 N.	1581	81.50	80.04	−1.46	Very warm valley near the Rio Bogota.
Les Paramos	4 36 —	11480	47.30	48.86	+1.56	Top of a mountain-pass.
Carthago	4 46 —	3149	74.84	74.24	−0.60	Very warm valley of Cauca.
Tunja	5 05 —	9522	56.66	54.09	−2.57	Among the mountains of New Grenada.
Santa Fé de Bogota	5 24 —	8721	57.74	56.30	−1.44	Plain surrounded with hills, vegetation very luxuriant.
Tomependa	5 33 S.	1279	78.44	80.90	+2.46	Surrounded by thick woods, on the Amazons.
Caxamarca	6 54 —	9381	60.80	54.01	−6.79	Extensive plateau, sky serene, sheltered by mountains free from snow.
Pamplona	7 01 N.	8016	61.16	57.92	−3.24	Plain surrounded by mountains.
Antioquia	7 14 —	1666	77.00	78.97	+1.97	About two leagues from the river Cauca.
Caripe	9 50 —	2950	65.30	73.31	+8.01	Thick and damp forests.
Cumana	10 27 —	....	81.86	84.14	+2.28	Sea-coast.
Caraccas	10 31 —	2906	69.44	73.17	+3.73	Foggy sky, valley of small extent.
Antilles	17 00 —	....	81.05	80.26	+0.21	
Vera Cruz	19 11 —	....	78.08	78.58	+0.50	
Havannah	23 10 —	....	78.08	75.05	−3.03	
Orotava	28 25 —	....	69.80	69.54	−0.26	
Natchez	31 28 —	....	64.80	65.94	+1.14	
Williamsburg	38 08 —	....	58.00	57.20	−0.80	
Cincinnati	39 06 —	512	53.70	53.82	+0.12	
Philadelphia	39 56 —	....	54.90	54.65	−0.25	
New York	40 40 —	....	53.80	53.60	−0.20	
Cambridge	42 25 —	....	50.40	51.05	+0.65	
Ipswich	42 38 —	....	50.00	50.73	+0.73	
Quebec	46 47 —	200	41.90	43.68	+1.78	
Nain	57 10 —	....	26.40	28.23	+1.83	
Okak	57 20 —	....	29.80	27.97	−1.83	
Fort Churchill	59 02 —	....	25.30	25.30	0.00	
Winter Harbour Melville Island	74 47 —	....	1.33	3.52	+2.19	

Convenience of Brewster's formula. (236.) Of all the formulæ, however, which have been contrived to enable us to approximate readily to the probable mean temperature of a place, at the level of the sea, that before given, and represented under the form of

$$81.5 \cos L,$$

is most distinguished for its simplicity, and on the whole agrees best with observation; and as it is often useful to be able at once to refer to a Table which shall indicate, within certain limits, the mean temperature of a given parallel, we have computed the following Table.

TABLE XLII.

Latitude.	Mean Temperature.	Latitude.	Mean Temperature.
0°	81°.50	46°	56°.61
1	81.49	47	55.58
2	81.45	48	54.53
3	81.39	49	53.47
4	81.30	50	52.39
5	81.19	51	51.29
6	81.05	52	50.18
7	80.89	53	49.05
8	80.71	54	47.90
9	80.50	55	46.75
10	80.26	56	45.57
11	80.00	57	44.39
12	79.72	58	43.19
13	79.41	59	41.98
14	79.08	60	40.75
15	78.72	61	39.51
16	78.34	62	38.26
17	77.94	63	37.00
18	77.51	64	35.73
19	77.06	65	34.44
20	76.58	66	33.15
21	76.09	67	31.84
22	75.57	68	30.53
23	75.02	69	29.21
24	74.45	70	27.87
25	73.86	71	26.53
26	73.25	72	25.18
27	72.62	73	23.83
28	71.96	74	22.46
29	71.28	75	21.09
30	70.58	76	19.72
31	69.86	77	18.33
32	69.12	78	16.94
33	68.35	79	15.55
34	67.57	80	14.15
35	66.76	81	12.75
36	65.93	82	11.34
37	65.09	83	9.93
38	64.22	84	8.52
39	63.34	85	7.10
40	62.43	86	5.69
41	61.51	87	4.27
42	60.57	88	2.84
43	59.61	89	1.42
44	58.63	90	0.00
45	57.63		

Temperature of the Interior of the Earth.

Introductory remarks.

(237.) Fourier, in his elaborate and interesting Treatise on the analytical theory of Heat,* has properly remarked, that the question of terrestrial temperatures offers one of the most beautiful applications of the theory of Heat. The different parts of the surface of the globe, says he, are unequally exposed to the impression of the solar rays, and the intensity of this action depends on the latitude of the place, on the changes which take place during the day and the night, and on the effects of other inequalities of a less sensible kind. Between this variable condition of the surface, and that of the temperature of the atmosphere, some relation must exist, which a well-devised theory must ultimately unfold.

Howard's observations on the influence of the Earth's temperature on the atmosphere.

(238.) The heat existing from day to day in that portion of the atmosphere which is next the Earth, is at no time, says Mr. Howard, the simple product of the direct action of the solar rays on that portion; and the accumulation of heat near the surface, is evidently due to the stopping of the rays at that surface; to their multiplied reflections and refractions, in consequence of which they are as it were absorbed and fixed, for a time, in the soil and in the incumbent atmosphere. By this process, the Earth, when in a cold state at the end of winter, becomes gradually heated to a certain depth as the warm season advances; and, on the other hand, as the Sun declines in autumn, the heated soil acts as a warm body on the atmosphere, and gives out again the heat it had received, and as it were stored up. Similar vicissitudes during the day and the night, according as the Sun's action is exercised or withdrawn from the terrestrial surface, contribute in their part to that unceasing variety which characterises all the conditions of the great body of air surrounding it.

Influence of the solar rays on the Earth's surface.

(239.) It appears from experiments that have been made, that were the Earth's surface at a mean temperature, and the solar rays suddenly intercepted, it would require about thirty days to cool it down seven degrees, and about the same time to heat it to its former temperature, on their return. In fig. 2 is a diagram, constructed originally by Mr. Howard to illustrate this interesting subject. The oblique circle marked with the signs of the Zodiac denotes the varying declination of the Sun, and the irregular line which intersects it in something like opposite nodes, represents the curve of temperature for a year. The area comprised between the line of temperature and the Sun's path, and shaded with parallel lines, represents the cold produced by absorption on the side turned towards Spring; and the nearly similar portion covered with dots, and turned towards autumn, the heat derived by the atmosphere from the Earth's radiation. A like figure might be constructed to illustrate the vicissitudes of day and night, and may serve to illustrate, in a general way, the effect which the temperature of the Earth exercises on the great volume of the air.

Condition of the Earth's internal temperature.

(240.) Our knowledge, however, of the actual condition of the Earth's internal temperature, must be derived from observations made below its surface. By pursuing the subject, Philosophers have discovered that, at a certain depth below the surface, the temperature preserves a nearly constant character during the circling changes of the year; and this permanent temperature is less, according as the place is more distant from the Equator. The great volume of the Earth, therefore, may be supposed to be separated into two portions;—the exterior, which may be regarded as a kind of envelope, of a thickness incomparably less than the length of the terrestrial radius, and subject to the greatest vicissitudes of temperature; and an internal mass, or nucleus, of a form nearly spherical, the surface of which may be subject to a constant temperature,* through all the points of what may be denominated, in a general way, a given parallel, but which undergoes a variation in passing from one parallel to another.† It

Division of the Earth's volume into two portions.

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* *Théorie Analytique de la Chaleur, par* M. Fourier, à Paris, 1822.

* To investigate the conditions of a great internal Isothermal plane, will open, at some future time, a noble subject for Philosophical inquiry.

† To treat this inquiry in all its generality, would be to follow Fourier through all the stages of his profound and valuable Work; to advance with him through his multiplied and refined applications of the Differential Calculus, to pass through the successive orders of his integrals, and sum the varied and important series which have enabled him to trace the law of the propagation of heat in a solid sphere. Our limits will by no means permit us to do this, and we can only recommend his elaborate Work to the deepest attention of our readers.

We may, however, briefly remark, that the general equations relating to the propagation of heat belong to the calculus of partial is the consideration of the former of these, that more immediately interests the Meteorologist, and to which we shall now briefly direct the attention of the reader.

Observations made in Caves at the Observatory of Paris.

(241.) Among the most interesting and important observations that have been made to prove the existence of a plane below the surface of the Earth, which preserves during all the mutations and changes of the year a nearly invariable temperature, may be mentioned the results obtained in the Caves below the Observatory at Paris, and of which the following Table contains an abstract for three years, together with the temperature of the Earth's surface during the same period, both in degrees of the centigrade scale.

Table XLIII.

Months.	Mean Temperature of the Caves for 1826.	Mean Temperature on the Surface of the Earth for 1826.	Mean Temperature of the Caves for 1827.	Mean Temperature on the Surface of the Earth for 1827.	Mean Temperature of the Caves for 1828.	Mean Temperature on the Surface of the Earth for 1828.
January	12°.161	− 1°.7	12°.172	− 0°.2	12°.194	+ 5°.9
February	12.165	+ 6.4	12.175	− 0.9	12.202	+ 5.2
March	12.170	+ 7.4	12.175	+ 8.0	12.230	+ 7.0
April	12.174	+10.2	12.176	+11.4	12.191	+10.8
May	12.170	+12.6	12.176	+14.6	12.195	+15.1
June..................	12.182	+18.8	12.176	+17.0	12.197	+17.5
July	12.171	+20.7	12.166	+19.8	12.193	+19.1
August..............	12.171	+21.2	12.171	+18.0	12.190	+17.6
September	12.170	+17.1	12.181	+16.2	12.210	+16.6
October..............	12.170	+13.4	12.182	+13.1	12.210	+10.8
November	12.168	+ 5.4	12.184	+ 5.8	12.215	+ 7.4
December.	12.171	+ 5.8	12.187	+ 6.9	12.212	+ 4.5
Mean	12.170	+11.44	12.177	+10.8	12.203	+11.5

From these observations it may be inferred, that while an uniform temperature is nearly preserved through the whole series of observations made in the Caves, an *increase* of temperature will be found from the surface to the point where the limit is attained, during the months of January, February, March, April, November, and December; but during the remaining months, a *decrease* of temperature takes place, till it has gained a like point of uniformity.

(242.) If Caves of a like nature existed in different latitudes, and observations of an equally accurate kind could be made in them, a most important series of results might be obtained, respecting the internal temperature of the Earth. But as this is obviously impossible, observations have been made at various depths, as circumstances would permit. Saussure, among others, made an interesting set of observations near Geneva, in October 1785. At the depth of 4 feet, he found the temperature to be 60°.8; at 16 feet 56°; at 21 feet 53°.6; and at 28 feet 51°.8; the temperature, at the surface, having been 60°.3, by Fahrenheit's scale. A thermometer, also, which had been placed 31 feet below the surface of the earth, when examined in summer, indicated a temperature of 49°.5; whereas a similar observation made in winter was 52°.2. It is

Observations of Saussure.

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differences, and though their forms are very simple, they are not susceptible of integration by the ordinary methods.

The question of the propagation of heat depends on the integration of an equation of the form

$$\frac{dv}{dt} = K\left(\frac{d^2 v}{dx^2} + \frac{2}{x} \cdot \frac{dv}{dx}\right),$$

so that the integral is satisfied when $x = X$, at the same time $\frac{dv}{dx} + hv = 0$. The functions h and K represent, respectively, the ratios $\frac{h}{K}$ and $\frac{K}{C\,D}$, the four elements being specific coefficients which the progress of the inquiry developes. The function v denotes the temperature observed in a spherical lamina whose radius is x, after the time t. X is the radius of the sphere, and v is a function of x and t, equivalent to Fx when we suppose $t = 0$. The function Fx is given, and represents the initial and arbitrary state of the solid.

In applying this general equation to the propagation of heat in a solid sphere, it assumes the form

$$\frac{vx}{2} = \frac{\sin n_1 x \int x \sin n_1 x \, F x \, . \, dx}{X - \frac{1}{2 n_1} \sin 2 n_1 X} e^{-kn_1^2 t}$$

$$+ \frac{\sin n_2 x \int x \sin n_2 x \, F x \, dx}{X - \frac{1}{2 n_2} \sin 2 n_2 X} e^{-kn_2^2 t} + \&c.$$

which satisfies all the conditions of the problem.

In treating of the practical applications of the subject, it may be remarked, that we can only arrive at a knowledge of it, by measuring the temperatures of subterraneous excavations, or of those springs which issue from the depths of the earth. The small depths, however, to which the persevering industry of Man has penetrated, form but a small portion of the terrestrial radius. Cordier has properly remarked, in his excellent Paper on Subterranean Temperatures, that as it is proposed to apply ultimately to the great, the inferences deduced from the minute, the smallest errors will exercise a prodigious influence upon what is to be inferred respecting the temperature of the entire mass of the globe. If we proceed according to the approximative law deduced from the experiments hitherto published, an error of one degree of Fahrenheit in excess, for a depth of 180 feet in a given Country, will cause the point at which it is presumed water would boil, to approach within 1600 feet of the place of observation. And, again, if we compare the depth of the deepest mine in which observations have been accurately made on subterranean temperatures, with the entire length of the terrestrial radius, we shall find the latter dimension to exceed the former, nearly in the ratio of 20,000 to 1; a ratio sufficient to inspire the most salutary caution, when the attempt is to deduce the Physical condition of the antecedent from that of the consequent.

worthy of remark, that the greatest of these temperatures was found in winter. A series of observations made near the same place, and continued for ten years, proved that the minimum temperature occurred when the greatest heat prevailed in the atmosphere, and the maximum at the time of the greatest cold.

Observations of Mr. Fox.

(243.) Mr. Fox,[*] of Falmouth, also has made many interesting observations relative to the influence of the seasons on the temperature at considerable depths. In fig. 3., which refers to Dolcoath mine in Cornwall, A represents the bottom of the engine shaft 235 fathoms deep; B C the deepest galleries, or levels, on the course of the vein at 230 fathoms deep, and D E galleries 220 fathoms deep on the same vein. A great portion of the water finds its way to A, whence it is pumped by a steam-engine, the quantity discharged in 24 hours being 500,000 gallons. At the point *a*, a stream issued whose temperature was 82°, and at *e*, another stream, whose temperature was 78°, the air near A being 80°.[†] A hole, three feet in depth, was made at O in the deepest level, 15 fathoms from the engine shaft. It was usually quite dry, and for some years no men had been employed nearer to it than at A. In this hole was inserted the bulb of a thermometer, four feet in length, the space round the lower extremity of the instrument being carefully filled with clay. The persons employed below D E were usually two, and occasionally three at a time, on an average two and a quarter constantly. In D E there were four or five at a time.

In the galleries,	10 fathoms higher up,		10 men at a time.	
Ditto	10	ditto	14	ditto.
Ditto	10	ditto	14	ditto.

The total number of men was 360, but, as each worked only six hours at a time, 100 may be regarded as the average number constantly at work in the mine. From the erroneous views which have been entertained up to a late period on this very important subject, the minute attention given to all the conditions of this experiment will not be undervalued.

No alteration from the seasons.

(244.) The thermometer which was placed at O in January 1821, being examined in September 1822, exhibited no alteration from the seasons; but other thermometers buried eight inches in the rock, at different stations, in many of the superior galleries of the mine, (that nearest the surface being 100 fathoms deep,) indicated temperatures varying, according to the depth, from 57°.5 to 70°. The surface of the mine is about 62 fathoms above the level of the sea, the deepest workings being in granite, and those nearer the surface in clay slate.

(245.) The Treskerby Mine, which is worked under circumstances of strata and elevation very similar to Dolcoath, had the following observations made in it. In December 1819 the temperature at the surface being 50°, those of two streams proceeding from the opposite extremities of the deepest gallery, 149 fathoms below the surface, were 72° and 76°. The temperature of these streams was precisely the same in January 1820, when the surface was two degrees below the freezing point. In September of the same year, the temperatures of the streams were respectively 73° and 76°, when the air at the surface was 67°.

Monthly observations made in Cornwall.

(246.) Mr. Fox has also recently given us a series of Monthly observations, made in the Mines of Huel Gorland and Dolcoath, in the IIId volume of the *Transactions of the Royal Geological Society of Cornwall.* The thermometers were circumstanced like those first alluded to. The results are contained in the next Table.

TABLE XLIV.

Months.		Huel Gorland.	Dolcoath.
1823	June	52°.74	53°.60
	July	53.94	53.35
	August	55.30	56.60
	September	56.20	57.80
	October	53.70	52.70
	November	49.10	49.67
	December	46.00	47.57
1824	January	44.00	44.44
	February	43.63	44.85
	March	42.80	44.08
	April	43.78	44.62
	May	46.69	47.85
	Means	48.99	49.94

The mean annual temperature of Falmouth in the vicinity of these Mines is 50.67.

Observations of Mr. Ferguson.

(247.) Professor Leslie has likewise given us a series of excellent observations made by Mr. Ferguson at Abbotshall in latitude 56° 10′ North, in which mercurial thermometers with stems of unusual length were employed. The results are contained in the next Table.

TABLE XLV.

Months	1816.				1817.			
	1 Foot.	2 Feet.	4 Feet.	8 Feet.	1 Foot.	2 Feet.	4 Feet.	8 Feet.
January	33°.0	36°.3	40°7	43°.0	35°.6	38°.7	40°.5	45°.1
February	33.7	36.0	39.0	42.0	37.0	40.0	41.6	42.7
March	35.0	36.7	39.6	42.3	39.4	40.2	41.7	42.5
April	39.7	38.4	41.4	43.8	45.0	42.4	42.6	42.6
May	44.0	43.3	43.4	44.0	46.8	44.7	44.6	44.2
June	51.6	50.0	47.1	45.8	51.1	49.4	47.6	47.8
July	54.0	52.5	50.4	47.7	55.2	55.0	51.4	49.6
August	50.0	52.5	50.6	49.4	53.4	53.9	52.0	50.0
September	51.6	51.3	51.8	50.0	53.0	52.7	52.0	50.7
October	47.0	49.3	49.7	49.6	45.7	49.4	49.4	49.5
November	40.8	43.8	46.3	45.6	41.0	44.7	47.0	47.6
December	35.7	40.0	43.0	46.0	37.9	40.8	44.9	46.4
Means	43.8	44.1	45.1	46.0	44.9	45.9	46.2	46.6

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[*] To this gentleman we are indebted for the first annunciation of the general law of an increase of temperature at considerable depths in the Earth, as well as for much of the information which has now so satisfactorily established its accuracy.

[†] To the same respectable authority we also refer for the fact that the mean temperature of the Earth's surface in a considerable portion of the mining district of Cornwall is below 50°.

Extensive observations now making by M. Arago.

(248.) Observations of a similar kind, but on a more extended scale, are at this time carrying on in the Garden of the Observatory at Paris, by the distinguished Astronomer M. Arago. The Scientific world waits with impatience for the results. It is obvious that all these observations must be much influenced by the peculiar conductibility of the solid mass, in or near which the thermometer of observation is placed.

The temperature below the Earth's surface varies with the latitude.

(249.) But the permanent temperature before referred to, although it may be constant for the same parallel, which however is extremely doubtful, varies considerably with the latitude, being less according as the place is more distant from the Equator. In the following Table it will be seen that between Vadso and Cairo, a difference of 40° of latitude, the temperature of the interior of the Earth varies 36°.5, and between the former place and Equinoctial America nearly 43°.

Table XLVI.

Places.	Latitudes.	Mean Temperature of the interior of the Earth.
Vadso................	70° 0′	35°.96
Berlin...............	52 31	49.28
Paris................	48 50	53.60
Cairo	30 2	72.50
Equinoctial America..........	......	77.00 78.08

Observations of Humboldt on springs.

(250.) Humboldt has remarked that from the Polar Circle to the Equator, and from the tops of mountains downwards to the plains, the progressive increase of the temperature of springs diminishes with the mean temperature of the ambient air. Wahlenberg also observes, that the mean temperature of the soil and subjacent rock rises higher and higher above that of the air, the further we advance towards the North.

Observations of Wahlenberg

The observations of Wahlenberg illustrating this remarkable result, were published by Von Buch in Gilbert's *Annals*, and compared with the temperature of the atmosphere. The following Table contains an abstract of the results, and perfectly illustrates the nature of the phenomenon.

Table XLVII.

Places.	Latitude.	Temperature of Spring.	Temperature of Atmosphere.	Difference.
At Carlscrona	56½°N.	47°.3	46°.2	1°.1
Upsal.................	60	43.7	42.1	1.6
Umea..................	64	37.2	33.3	3.9
Giworten Fiall, 1600 ſeet above the sea	66	34.2	25.2	9.0

Temperature of the air in mines.

(251.) Many interesting inquiries have also been made respecting the temperature of the air in mines, the results of which might be fairly regarded as representing the exact temperature of the zone of rock in which they are situated, had they been circumstanced like the Caves of the Observatory at Paris—uninfluenced by the presence of miners, freed from the access of water having the temperature of other strata, and also from the introduction of the external air.

Observations of M. Cordier.

(252.) The latest writer on this subject* is M. Cordier, who, in a Paper read before the Academy of Sciences in 1827 on subterranean temperatures, has ably discussed it. If we suppose for a moment, says he, what might take place in a mine of some extent, under the conditions here alluded to, we may fairly infer that the air in each stage would assume the temperature of the surrounding rock. And if we proceed on the hypothesis commonly received, and which seems justified by observation, that the heat increases in proportion to the depth, the air would continually circulate from the lower to the upper stages of the mine, and *vice versâ*, on account of the alteration of Specific Gravity, produced by the inequalities of heat at the different levels. A greater activity would prevail in these motions, the wider and less sinuous the subterranean excavations were, and the greater the number of their communications.

(253.) If, therefore, a uniformity of temperature would not be found to take place in the case of a mine circumstanced like one here alluded to, still less would it be found to prevail in common mines, to which the air has continual access, in which the filtering waters incessantly act as a cause of variation, and where the lights and workmen daily disengage large quantities of heat.

Influence o the external air.

(254.) Moreover, the external air, by continually mixing with the air contained in a mine, acts in the ratio of the temperature which it brings to each point, and of the mass which is introduced at the same point in a given time. These two elements are continually varying, and their influence necessarily extends to the most distant excavations. The temperature of the air which enters, varies every instant, and it is also influenced more or less in consequence of evaporation. At the same time the augmentation of temperature it may receive from the increasing effects of atmospheric pressure as the air penetrates into deeper cavities, cannot be considerable.†

Mean temperature of air introduced into a mine in a year, is less than the mean temperature of the year.

(255.) In pursuing these interesting considerations, Cordier has noticed the important fact, that the mean temperature of the mass of air introduced into a mine in the course of a year, is inferior to the mean temperature of the country for the same year. He estimates the difference at from three to five degrees of Fahrenheit, in most of the mines of our climates. Hence, not only does the introduction of the external air increase and diminish incessantly the temperature of the air contained in the different parts of each stage, but it also tends ultimately to lower the proper temperature of the whole excavation, and in an unequal manner, in different parts of the same level.

Effects of the filterin water.

(256.) The filtering water, which also operates as a disturbing cause, acts in an uniform manner, whether we consider its influence confined to a very short period, or extended to one very long. This cause tends to diminish the temperature of the air contained in the excavations in which it occurs, since it depends

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* Since this was written, Mr. Henwood has published a very interesting Paper on the Temperature of Mines in the *Edinburgh Journal of Science*, No. XX.

† The increment of temperature produced by the increased atmospherical column has been much overrated. Cordier, with juster views, estimates the increased effect at about five or six tenths of a degree of Fahrenheit, for a depth of 180 feet.

upon the influence of the proper heat of the affluent waters; and these waters arrive at the point whereat they make their exit, with a temperature derived from more elevated zones of rocks. There is, indeed, an infinity of chances against the water of filtration and springs indicating a temperature perfectly equal to that of the rock from which they issue. The temperature of the rain-water which penetrates into the soil continually varies, being sometimes superior, and sometimes inferior to the mean temperature of the Country. The original degree of heat is also subject to many modifications, dependent on the depth to which the waters descend, the number and length of the canals, the slowness of the circulation, the length of time that it has been established, and the number and extent of the masses of water traversed, if there be any such in the lines of passage.

Anomalous results derived from the temperature of springs in mines.

(257.) A multitude of results have been obtained respecting the temperature of springs in mines, of the water of their engine pits, and also of those great inundations to which mines are occasionally subject, but the conclusions derived from them are by no means satisfactory. In many of them, the expressions of the increase of heat which have been found in the same mine, present variations, the extent of which infinitely surpasses that which might be admitted as resulting from anomalies arising from particular circumstances of the rock, or from those inaccuracies to which observations of this kind are liable.

Influence of workmen and lights.

(258.) Another disturbing cause arises from the heat disengaged by the workmen and the lights, which produces an effect the reverse of the preceding. According to the calculations of M. Cordier, the grounds of which are added in a note,* the presence of two hundred miners, and two hundred lamps suitably distributed, would be sufficient to raise a volume of air, which should fill a gallery whose length is 656,900 feet, (nearly 124 miles,) and transverse section 6 feet by 3 feet, one degree of Fahrenheit in an hour.

M. Cordier's results.

(259.) M. Cordier's results respecting the depths at which a depression of a degree of Fahrenheit's thermometer is found, are exceedingly variable. They may be useful to our readers in helping them onwards in the investigation, and we therefore subjoin them.

Observations derived from Springs in Mines.

1. By four observations made in three mines in Saxony, the depth at which a depression of a degree of Fahrenheit is found, varies from 102 to 64 feet, mean 83 feet.
2. By three observations made at Poullaouen, in Bretagne, the same result was obtained, from 351 to 82 feet, mean 206 feet.
3. By four observations at Huelgoët, a similar result was obtained, from 90 to 36 feet, mean 57 feet.
4. By one observation at Dolcoath, 45 feet was obtained.
5. And by one observation made at Guanaxuato, 46 feet.

Observations made on the Temperature of Water in Engine-Pits of Mines.

From these observations it was found, that the depth corresponding to the increase of one degree of heat would be, in round numbers, as follows:

1. By six observations made in four mines of Cornwall, from 37 to 27 feet, mean 32 feet.
2. By three observations made in three mines of Devonshire, from 71 to 35 feet, mean 60 feet.
3. By one observation made at the salt mine of Bex, in Switzerland, 48 feet.
4. And by two observations at Poullaouen, in Bretagne, from 137 to 95 feet, mean 116 feet.

Observations made on the Temperature of Water of great Inundations in Mines.

From these observations it was found, that the depth corresponding to the increase of one degree Fahrenheit, will be, in round numbers, as follows:

1. By seven observations, made in seven mines of Cornwall, from 75 to 23 feet, mean 52 feet.
2. By one observation in a mine of Saxony, 63 feet
3. And by one observation at Huelgoët, 56 feet.

Lastly, by means of Observations made on the Temperature of the Rock in Mines,

we find the depth corresponding to the increase of one degree of heat, as follows:

1. By two series of observations made during two years, in two points of the mine of Beschert Glück, in Saxony, the depth being from 101 to 68 feet, mean 84 feet.
2. By four series of observations made in 1815, in four points of the mine of Alte Hoffnung Gotes, in Saxony, from 175 to 64 feet, mean 93 feet.
3. By two observations made cursorily in the consolidated mines in Cornwall, 31 feet.
4. And by a series of observations which lasted 18 months, in a part of the Dolcoath mine, 54 feet.

(260.) Our limits will not permit us to do justice to

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* According to the researches of M. Despretz on Animal Heat, a middle-sized man disengages, in twenty-four hours, by respiration, a quantity of heat equal to that which would raise one ounce of water to 205°.709 Fahrenheit, and this heat is only three-fourths of the quantity produced by the same individual during that time. Hence it follows that the total heat disengaged in an hour is equivalent to what would raise 4640 pounds of water one degree of Fahrenheit. By employing the ratio 1.000 : 0.2669, which according to MM. Berard and De la Roche expresses the difference of the Specific Heats of water and air, and adopting the Specific Gravity possessed by air at a temperature of 54° of Fahrenheit, it is found that a miner disengages hourly a quantity of heat capable of raising one degree of Fahrenheit, a cubic mass of air containing 34,456 feet, taken at the temperature of 54°.

Of the effects produced by the lights employed in mining two cases necessarily arise, according as oil or candles are employed. If linseed oil be employed, the combustion of one ounce will, according to the experiments of Rumford, raise the temperature of an ounce of water to 16°.28 of Fahrenheit; and hence Cordier remarks, that the presence of a lamp burning 15 grammes of oil, increases by one degree of Fahrenheit the temperature of a mass of air of 26,000 cubic feet, taken at the before-mentioned temperature of 54°. Thus, four of these lamps produce about as much heat as three workmen.

Count Rumford also found, that the heat furnished by the combustion of one ounce of tallow raised an ounce of water to 15°.064 Fahrenheit; and hence it follows that, in a single hour, the light obtained by the consumption of 7½ grammes of candles, raises 12,015 cubic feet of air one degree of Fahrenheit's scale, taken at the original temperature of 54° Fahrenheit.

These facts will be found of great value and importance to our readers, in pursuing the interesting problem of the Earth's temperature, as connected with the subject of mines.

Irregularity in distribution of Internal Heat.

Isothermal lines within the Earth.

this very important subject, and we can, therefore, only briefly remark, that the connection existing between some of the mutations of the atmosphere and the internal temperature of the Globe, renders it worthy of a more extended investigation. An idea started by Cordier, at the end of his excellent Paper, opens also a new field for Philosophical inquiry. "The differences," says he, "between the results collected in the same place, do not depend solely upon the imperfect nature of the experiments, but also upon a certain irregularity in the distribution of the subterranean heat in different Countries." This idea, replete with interest both to the Meteorologist and the Geologist, will, we trust, be effectually explored by the many active and patient cultivators of natural knowledge with which happily the present period abounds.* In the mean time we must not omit the observation of Mr. Fox, that "the Isothermal lines within the Earth may in some measure coincide with the form of its surface."

Influence of the Ocean.

(261.) We have only room to add the single remark, that the lower strata of the atmosphere are also influenced by the temperature of the waters of the Ocean; and forming as they do so considerable a portion of the Globe, could not be omitted in an inquiry of this kind. Although the sea radiates less absolute heat than continents, it exercises an important effect on the portion of the atmosphere resting on it, in consequence of evaporation. It sends the particles of water which are cooled, and therefore heavier, towards the bottom; and it is heated again, or cooled, by the currents directed from the Equator to the Poles, or by the mixture of the superior and inferior strata on the sides of banks. Having also alluded to some of the phenomena connected with the temperature of the Ocean in a preceding part of the Paper, we conclude by adding

TABLE XLVIII.

Containing the Results of some Observations made by late Navigators on the Temperature of the Ocean, at various Depths below its Surface.

Position.		Temperature of the		Depth in Fathoms.	Temperature at the Depth in preceding Column.	Difference between the Temperature of Surface Water and that sounded to.	Names of Observers.
Latitude.	Longitude.	Air.	Surface Water.				
80° 0′ N.	5° 0′ E.	40°.0	29°.7	120	36°.3	6°.6	Scoresby.
79 4	5 4	34.0	29.0	13	31.0	2.0	Ditto.
......	......	....	....	37	33.8	4.8	Ditto.
......	......	....	....	57	34.5	5.5	Ditto.
......	......	....	....	100	36.0	7.0	Ditto.
......	......	....	....	400	36.0	7.0	Ditto.
79 4	5 38	38.0	29.0	730	37.0	8.0	Ditto.
78 2	0 10 W.	36.0	32.0	761	38.0	6.0	Ditto.
78 0	......	40.5	....	118	31.0	....	Lord Mulgrave.
77 4	2 30 E.	30.0	29.0	50	29.3	0.3	Scoresby.
......	......	....	....	100	31.0	2.0	Ditto.
77 15	8 10	16.0	29.3	20	29.3	0.0	Ditto.
......	......	....	....	40	29.3	0.0	Ditto.
......	......	....	....	60	30.0	0.7	Ditto.
......	......	....	....	100	30.0	0.7	Ditto.
76 34	10 50	25.0	30.0	20	31.0	1.0	Ditto.
......	......	....	....	40	35.0	5.0	Ditto.
......	......	....	....	60	34.0	4.0	Ditto.
......	......	....	....	100	34.7	4.7	Ditto.
76 16	10 50	16.0	28.3	20	28.9	0.3	Ditto.
......	......	....	....	50	28.3	0.0	Ditto.
......	......	....	....	123	30.0	1.7	Ditto.
......	9 0	12.0	28.8	50	31.8	....	Ditto.
......	......	....	....	123	33.8	....	Ditto.
......	......	....	....	230	33.3	....	Ditto.
75 28	60 36 W.	....	34.0	314	32.0	2.0	Ross.
75 2	105 14	31.0	30.0	94	31.25	1.75	Parry.
73 37	77 28	....	34.5	80	32.0	2.5	Ross.
73 35	89 1	39.0	34.0	185	34.0	....	Parry.
Winter	Harbour	−16.0	+28.0	5	30.0	2.0	Ditto.
72 7	19 11 W.	42.0	34.0	118	29.0	5.0	Ditto.
72 5	76 0	31.0	30.5	110	30.25	0.25	Ditto.
72 0	73 0	33.0	32.0	75	32.25	0.25	Ditto.
71 24	71 0	38.0	35.0	88	33.0	2.0	Ditto.
69 0	......	59.5	....	673	32.0	....	Lord Mulgrave.
68 25	65 0	34.0	32.0	35	31.5	0.5	Parry.
68 24	63 32	31.0	30.5	170	30.5	0.0	Ditto.
......	63 8	29.0	30.0	318	30.0	....	Ditto.
68 12	60 5	31.5	32.0	770	33.0	1.0	Ditto.
68 19	60 5	34.0	32.0	146	34.0	2.0	Ditto.

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* We recommend the whole of Cordier's Paper to the particular attention of our readers. A translation of it may be seen in the Xth and XIth numbers of the *Edinburgh New Philosophical Journal*, edited by Professor Jameson. M. Cordier has also been occupied with some experiments of his own on this highly interesting subject, for which the learned wait with impatience.

Position.		Temperature of the		Depth in Fathoms.	Temperature at the Depth in preceding Column.	Difference between the Temperature of Surface Water and that sounded to.	Names of Observers.
Latitude.	Longitude.	Air.	Surface Water.				
68° 0′ N.	60° 9′ W.	34°.0	31°.0	809	27°.0	4°.0	Parry.
......	60 0	30.0	34.5	200	33.25	1.25	Ditto.
67 0	......	48.5	....	810	26.0	....	Lord Mulgrave.
61 11	31 12	48.0	47.5	320	44.25	3.25	Parry.
60 44	59 20	....	....	100	30.0	....	Ross.
60 44	59 20	....	....	200	29.0	....	Ditto.
......	......	....	....	400	28.0	....	Ditto.
......	......	....	....	660	25.5	....	Ditto.
59 40	47 46	35.0	37.0	260	39.0	2.0	Parry.
58 52	48 12	38.5	38.5	290	38.75	0.25	Ditto.
57 44	47 31	46.0	45.0	650	40.5	4.5	Capt. Franklin.
57 39	13 31	50.0	49.5	140	47.8	1.7	Parry.
57 26	25 11	49.0	49.0	130	48.0	1.0	Ditto.
57 0	17 52	50.5	50.0	100	49.0	1.0	Ditto.
56 59	24 33	49.0	48.5	1020	45.5	3.0	Ditto.
39 4	13 8	72.5	69.1	138	56.0	13.1	Kotzebue.
39 27	12 57	71.1	68.5	100	56.7	11.8	Ditto.
37 3	199 17	63.0	61.0	10	59.5	1.5	Ditto.
36 9	148 9	73.0	71.9	25	57.1	14.8	Ditto.
......	......	....	....	100	52.8	19.1	Ditto.
......	......	....	....	300	44.0	27.9	Ditto.
36 0	15 0	72.5	75.0	95	74.7	1.7	Krusenstern.
35 51	147 38	75.0	72.0	100	51.0	21.0	Kotzebue.
29 24	199 26	75.0	74.0	100	62.0	12.0	Ditto.
27 50	152 22	77.1	77.0	200	51.5	25.5	Ditto.
23 3	181 56	....	78.0	25	75.0	3.0	Krusenstern.
......	......	....	....	50	70.5	7.5	Ditto.
......	......	....	....	125	61.5	6.5	Ditto.
20 30	83 30	....	83.0	1000	45.5	37.5	Sabine.
9 25	205 0	85.7	87.4	100	49.5	37.9	Kotzebue.
9 21	204 44	84.0	83.0	250	77.0	6.0	Ditto.
8 59	204 24	85.0	87.0	100	56.2	30.8	Ditto.
2 55	......	81.0	81.0	10	81.0	0.0	Bladh.
2 50	......	83.1	84.5	20	81.0	3.5	Ditto.
0 00	......	75.5	74.0	85	66.0	8.0	Wales and Bayley.
0 00	177 5	83.0	82.5	300	55.0	27.5	Kotzebue.
0 56 S.	146 16	82.0	82.0	100	60.0	22.0	Krusenstern.
3 26	7 59 E.	....	73.0	1000	42.0	31.0	Wauchope.
15 26	133 42 W.	79.8	80.0	10	79.0	1.0	Kotzebue.
18 17	124 56	79.2	78.5	125	68.5	10.0	Ditto.
24 0	......	72.5	70.0	80	70.0	0.0	Wales and Bayley.
30 39	345 33	68.0	67.0	35	49 5	17.5	Kotzebue.
34 44	......	60.5	59.0	100	57.0	2.0	Wales and Bayley.
55 40	......	47.0	40.5	110	51.5	11.0	Bladh.
44 17	57 31	57.6	54.9	196	38.8	16.1	Kotzebue.

Solar Radiation.

Solar Radiation.

(262.) Of the general laws which influence the radiation of caloric, we have already treated under HEAT. It will be our object in this part of the Essay on Meteorology, to direct the reader's attention to two beautiful examples of its power, denominated *Solar* and *Terrestrial* Radiation.

(263.) Many distinguished Philosophers have been occupied with the delicate and abstruse researches connected with the general question of radiation; but before the publication of Mr. Daniell's *Meteorological Essays*, the subject of Solar Radiation had hardly been emancipated from the region of conjecture. Dr. Wells, it is true, in his *Essay on Dew*, had shown its important relations to the vegetable kingdom, but scarcely any accurate attempts had been made to estimate the degree of Solar influence in any latitude, or at any elevation above the sea.

(264.) Mr. Daniell published his *Essays* in 1823, and it may, perhaps, surprise the reader of an after Age to learn, that at that date, and even at the time at which we are writing, no satisfactory answer can be given to the question—What is the maximum calorific impression which plants are subject to in any latitude? And influenced as the atmosphere is by the varying temperatures of the terrestrial substances acted upon by the Solar power, it becomes an interesting branch of Meteorological inquiry to examine, in all its generality, the principal conditions of this problem.

Difficulty of obtaining an exact measure of its power.

(265.) We shall, therefore, direct the reader's attention, in the first place, to Mr. Daniell's researches on this subject, and briefly review some of the objections that have been urged against them; at the same time earnestly impressing the importance of the question on the attention of the Philosophical inquirer. The thermometer employed by Mr. Daniell in his experiments on Solar Radiation was of the register kind, of a large range, having its bulb covered with black wool, and placed for observation about an inch above the Southern border of some garden mould, with a full exposure to the Sun. Mr. Daniell's results are contained in the following Table.

Experiments of Mr. Daniell.

TABLE XLIX.

Months.	Mean maximum of the air.	Mean maximum force of solar radiation	Maximum force of solar radiation.
January	39°.6	4°.4	12°
February	42.4	10.1	36
March	50.1	16.0	49
April	57.7	28.1	47
May	62.9	30.5	57
June	69.4	39.9	65
July	69.2	35.8	55
August	70.1	33.1	59
September	65.6	32.7	54
October	55.7	27.5	43
November	47.5	6.7	24
December	43.2	5.4	12

Solar Radiation varies with the declination,

(266.) From this Table it appears, that the power of the Solar Radiation varies with the declination. The greatest intensity, it will be remarked, occurs in June, while the maximum mean temperature of the atmosphere does not take place till July. This beautiful arrangement of nature has no doubt, as Mr. Daniell properly remarks, an important influence upon the processes of fructification, in the whole range of the vegetable kingdom. Agriculturists are well aware of the advantage of direct Solar heat in the flowering of wheat and other corn crops; an advantage which is never compensated by any elevation of temperature under a clouded sky.

and also during the different hours of the day.

(267.) But not only does the power of the Solar Radiation vary with the declination, and change with the successive seasons of the year, but during the day it likewise undergoes great modifications, increasing with the altitude of the sun from its appearance in the East until it has a little passed its meridian splendour; and again declining, till evening. In order to determine the system of changes, Mr. Daniell selected a perfectly calm and cloudless day in June, and his results are registered in the following Table.

Experiments to illustrate it.

TABLE L.

Time.	Temperature in the sun.	Temperature in the shade.	Difference.
A. M. 9h	93°	68°	25°
9½	103	69	34
10	111	70½	40½
10½	119	71	48
11	124	71½	52½
11½	125	72½	52½
12	129	73	56
P. M. 0½	132	74	58
1	141	74½	66½
1½	140	75	65
2	143	75½	67½
2½	138	76	62
3	138	76½	61½
3½	132	77	55
4	124	76	48
4½	123	77	46
5	112	76	36
5½	106	75	31
6	100	73	27
Means.....	124¾	73½	51¼

(268.) In the next Table, derived also from the authority of Mr. Daniell, are recorded the mean results of five other sets of experiments directed to the same point.

TABLE LI.

Time.	Force of the Sun's rays.
A. M. 9½	32°
10½	46
11½	55
12½	63
P. M. 1½	65
2½	63
3½	58
4½	49
5½	35
7½	29

Captain Sabine's experiments on the same subject at Sierra Leone.

(269.) At the time Captain Sabine was engaged in his inquiries with Captain Kater's pendulum in the tropical regions, he undertook to repeat Mr. Daniell's experiments. His first observations were made at Sierra Leone, and are recorded in the two succeeding Tables. The numbers in the column marked 1, are the means of two thermometers, one having a silvered and the other a blackened bulb. Those recorded in No. 2. were derived from a thermometer with a blackened bulb. The results of No. 3. are from a similar thermometer placed *in vacuo* in a glass-case. No. 4. indicates the temperature derived from a thermometer in the same glass-case with No. 3. but having its bulb enclosed in a double case of polished silver, not in contact with the glass or bulb. No. 5. denotes the numbers derived from a differential thermometer placed *in vacuo*, the sentient ball being coloured dark, and the other enclosed in a double case of polished silver. The divisions of this last were according to the millesimal scale.

TABLE LII.

Day and Hour.	No. 1.	No. 2.	Difference.	No. 3.	No. 4.	Difference.	No. 5.	Observations.
March 2d. A.M. 10h	79°.3	95°.0	15°.7	110°.0	—	—	70°	
11	80.0	93.0	13.0	109.0	—	—	78	
12	80.2	91.5	11.3	105.0	—	—	82	Haze.
P.M. 1	81.1	88.0	6.9	109.0	102	7.0	81	More clear and wind freshening.
2	80.9	85.0	4.1	109.5	102	7.5	64	Light clouds.
3	83.4	91.0	7.6	118.0	107	11.0	70	Clear.
4	82.9	90.0	7.1	116.0	108	8.0	53	Wind dying away.
5	81.4	83.5	2.1	100.0	98	2.0	—	
5½	80.0	81.5	1.5	86.0	86	0.0	—	

TABLE LIII.

Day and Hour.	No. 1.	No. 2.	Difference.	No. 3.	No. 4.	Difference.	No. 5.
March 4. A. M. 9	80°.0	95°.0	15°.0	110°	102°	8°	69°
10	80.5	93.0	12.5	110	105	5	79
11	80.0	94.0	14.0	110	105	5	86
12	80.2	98.5	18.3	115	108	7	93
P. M. 1	80.8	96.0	15.2	118	108	10	88
2	81.0	97.0	16.0	118	110	8	77
3	83.0	90.5	7.5	113	105	8	69
4	82.5	89.5	7.0	109.5	102	7.5	59

Further experiments at Bahia and Jamaica.

(270.) Other experiments tending to like results were performed by Captain Sabine, at Bahia, on the coast of Brazil, and at Port Royal in the Island of Jamaica; and from their united testimony, compared with that derived from his own experiments in London, Mr. Daniell was led to the conclusion, that the intensity of the Solar Radiation diminishes as we approach the Equator. This distinguished Meteorologist became, also, confirmed in his views on the subject, when, by referring to some experiments performed by Captain Parry at Melville Island, he found greater effects recorded than were obtained in the same month, in the vicinity of London, thereby intimating an increase of Solar Radiation as we advance to the North. The results for Melville Island are entered in the next Table.

TABLE LIV.

Date.	Time.	Sun.	Shade.	Difference.
March 16.	A. M. 9^h	+24°	−24	48
	10	+27	−23	50
	11	+28½	−22	50½
	12	+29	−21	50
	P. M. 3	+19	−13	32
March 25.	12	+30	−25	55
	P. M. 1	+17	−22	39
	2	+25	−22	47
	3	+21	−22	43

Scoresby's observations.

(271.) Mr. Daniell's views on this subject were, moreover, strengthened by some interesting remarks of Scoresby, in his *Account of the Arctic Regions*. The force of the Sun's rays, observes that enterprising man, is sometimes remarkable. Where they fall upon the snow-clad surface of the ice, or land, they are in a great measure reflected, without producing any material elevation of temperature; but when they impinge on the black exterior of a ship, the pitch on one side occasionally becomes fluid, while ice is rapidly generated at the other; or, while a thermometer placed against the black paint-work on which the Sun shines, indicates a temperature of 80° or 90°, or even more, a cold of 20° is sometimes found to prevail on the opposite side of the ship. This remarkable force of the Sun's rays is accompanied with a corresponding intensity of light.

Daniell's estimate of the temperatures referred to by Scoresby.

(272.) To form some estimate of the temperature referred to by Mr. Scoresby, the author of the *Meteorological Essays* performed the following experiment. He covered the bulb of a thermometer with pitch to the thickness of about one-tenth of an inch, and suffered it to remain till it had become quite hard. He then held it at some distance from a fire, and remarked the following temperatures. At 110° the pitch might have been moulded into any form, and from 120° to 136° it rapidly approached fluidity, and at the latter temperature dropped from the ball. The degree denoted cannot, therefore, be placed lower than 120°; and if ice were forming at the same time in the shade, the force of the Solar Radiation could not, Mr. Daniell observes, have been less than 90°.

Another observation of Scoresby.

(273.) Another observation of Mr. Scoresby is adduced by Mr. Daniell in confirmation of the subject. The Sun broke through the clouds, says the former observer, and produced a powerful effect upon the temperature. At two A. M. the thermometer was 3° or 4° below zero. At eight o'clock it was + 6°, and at ten A. M. about 14° in the shade. But the genial influence of the Sun was still more striking. In sheltered air, it produced the feeling of warmth; the black paint-work of the side of the ship, on which the Sun shone, was heated to a temperature of 90° or 100°, and the pitch about the bends became fluid. Thus, while on one side was uncommon warmth, on the other was intense freezing. The radiating force of the Sun, therefore, must, Mr. Daniell thinks, have been 80° in the month of April.

Observations on the Polar regions by Richardson, Back, and Kendall.

(274.) Since the publication of Mr. Daniell's *Essays*, the subject of Solar Radiation in the Polar regions has been resumed by Dr. Richardson, the naturalist to the expedition under Captain Franklin, and pursued with an earnestness worthy of their splendid enterprise. In an Appendix to Captain Franklin's *Second Journey*, Dr. Richardson, Captain Back, and Lieutenant Kendall have furnished the results of many interesting experiments; and, although they are not in all cases capable of comparison with each other, in consequence of the different results obtained by mercurial and spirit-of-wine thermometers, yet many most valuable conclusions may be drawn from them.

Solar Radiation varies with the declination.

(275.) In the first place it may be fairly inferred from the register kept by Captain Back and Lieutenant Kendall, that the force of Solar Radiation varies with the declination, and is some function of it. This will be apparent from the next Table, which, though not embracing the whole circuit of the year, affords very strong evidence in favour of such a supposition.

TABLE LV.

Year.	Month.	Mean Force of Radiation.
1826	November	10°.78
	December	6.99
1827	January	15.29
	February	34.55
	March	45.16
	April	53.18

These results were obtained by the aid of spirit thermometers; the bulb of that exposed to the solar influence being covered with thin paper, blackened with China ink and indigo, and sheltered from the wind by a thin glass bottle, and the other protected from the effects of radiation by two metal cylinders.* The hours of observation from which the results of the preceding Table were deduced, were 8, 10, and 11 A. M., and 1, 2, and 4 P. M.; and after the middle of February, an observation was also regularly made at noon. The maximum excess of temperature derived from the direct action of the Sun above the temperature indicated at the same time by the thermometer in the metal cylinders was always recorded by the observers.

Confirmed by some experiments of Richardson.

(276.) The same principle also is confirmed in some degree by the results obtained for the months of May, July, and August, by Dr. Richardson, with the aid of mercurial thermometers employed under the same circumstances as the preceding. These are shown in the next Table, and though so limited and brief, are to be highly valued, in the infancy of an inquiry like the present, obtained as they were under circumstances so trying and difficult.

TABLE LVI.

Year.	Month.	Mean Force of Radiation.
1827	May	35°.39
	July	28.00
	August	26.12

It must be remarked, however, that some little uncertainty exists in the numbers from which the results for July and August were obtained, on account of the observer, Mr. Dease, having lent his watch to the Eastern detachment of the expedition, a sacrifice which was however repaid by other interesting results.

Various maxima obtained in the Polar regions.

(277.) The following Table contains the maximum temperatures that occurred during the expedition, connected with the Solar Radiation, the highest and lowest temperatures of the air in the shade, and the difference between the temperature at sunrise, which was generally the lowest in the twenty-four hours, and that at two P. M., which, on an average, was the highest. All the observations are thrown into periods of ten or eleven days.

TABLE LVII.

Date.	Maximum Temperature indicated by a blackened Thermometer exposed to the Sunshine.	Maximum Excess of a blackened Thermometer in Sunshine over one in the Shade.	Maximum Temperature of Air in the Shade.	Minimum Temperature of Air in the Shade.	Mean Difference of Temperature in the Shade at Sunrise, and 2 P. M.
Sept. 1825.					
1—10	....	....	+55°.0	+33°.0	2°.0
11—20	....	....	+60.5	+36.8	8.2
21—30	....	....	+52.6	+33.7	4.8
October.					
1—10	....	....	+40.3	+13.4	7.2
10—20	+50.0	+25.2	+32.0	+ 6.8	5.1
11—31	+30.0	+17.5	+31.0	−18.0	4.5
November.					
1 —10	+28.0	+35.0	+32.5	−20.5	4.6
11 —20	+32.0	+28.2	+18.0	−22.0	3.6
21 —30	+40.0	+17.5	+29.4	−12.0	1.5
December.					
1—10	+44.5	+28.0	+27.5	−42.6	2.7
11—20	+11.0	+16.0	− 0.5	−29.3	2.6
21—31	− 4.8	+25.5	− 5.0	−47.5	1.9
Jan. 1826.					
1—10	....	+23.0	− 8.8	−49.0	3.3
11—20	....	+27.0	− 3.0	−38.0	0.9
21—31	+17.0	+42.0	+11.8	−47.5	5.5
February.					
1 -10	+ 8.8	+30.0	− 3.0	−39.0	3.1
11—20	+39.0	+57.0	+27.8	−38.0	6.8
21—28	+38.5	+50.9	+22.1	−34.6	4.4
March.					
1—10	+50.8	+46.0	+31.8	−29.3	10.3
11—20	+52.0	+65.0	+ 7.2	−43.0	22.0
21—31	+62.0	+55.0	+20.5	−31.0	18.2
April.					
1—10	+90.0	+51.0	+93.7	−19.7	16.6
11—20	+82.0	+42.7	+41.6	− 1.0	16.4
21—30	+52.6	+23.5	+34.0	− 6.5	14.3
May.					
1—10	+71.5	+32.3	+45.0	+ 1.0	13.1
11—20	+85.5	+42.8	+51.5	+17.5	12.0
21—31	+85.0	+25.0	+61.0	+28.0	20.2
June.					
1—10	+97.0	....	....	....	....
11—20	....	....	....	....	....
21—30	....	....	....	....	....
July.					
1—10	....	....	....	....	....
10—20	+99.0	+35.0	+80.0	+37.0	18.9
21—31	+107.0	+38.5	+73.0	+34.0	13.7
August.					
1—10	+109.5	+42.0	+74.0	+33.5	13.1
11—21	+97.5	+32.0	+71.0	+41.5	5.1
21—31	+109.0	+41.5	+64.7	+35.0	15.2

Horary ol servations made duri May, July and Augu

(278.) Amidst the cheerless solitude of the fort immortalized by the name of the English Franklin, the entire month of May, and the greater portions of July and August, were dedicated to the object of watching the power of the Solar Radiation, during many successive hours of the day. In the next Table the results of the first mentioned month are recorded, and embrace twelve successive observations for each day, the maxima being all denoted by asterisks.

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* The thermometer was enclosed in a brass cylinder, an inch and a half in diameter, having a cover and bottom of the same material, fitted loosely to obtain a free passage to the air. This brass cylinder was shut up in another cylinder of tinned iron, four inches in diameter, which also gave free admission to the air. This apparatus completely answered the intended purpose; for even when the Sun shone brightly on the outer case, the enclosed thermometer indicated as low, and frequently a lower temperature, than one hung in the most shady spot that could be selected.

TABLE LVIII.—*Observations on Solar Radiation in May 1826, at Fort Franklin, Latitude 65° 12′ North, Longitude 125° 12′ West.*

May.	At 5 A.M.		At 8 A.M.		At 9 A.M.		At 10 A.M.		At 11 A.M.		At noon.		At 1 P.M.		At 2 P.M.		At 3 P.M.		At 4 P.M.		At 5 P.M.		At 6 P.M.	
	Temperature in Shade by Mercurial Thermometer.	Excess of Blackened Thermometer in the Sunshine.	Temperature in Shade by Mercurial Thermometer.	Excess of Blackened Thermometer in the Sunshine.	Temperature in Shade by Mercurial Thermometer.	Excess of Blackened Thermometer in the Sunshine.	Temperature in Shade by Mercurial Thermometer.	Excess of Blackened Thermometer in the Sunshine.	Temperature in Shade by Mercurial Thermometer.	Excess of Blackened Thermometer in the Sunshine.	Temperature in Shade by Mercurial Thermometer.	Excess of Blackened Thermometer in the Sunshine.	Temperature in Shade by Mercurial Thermometer.	Excess of Blackened Thermometer in the Sunshine.	Temperature in Shade by Mercurial Thermometer.	Excess of Blackened Thermometer in the Sunshine.	Temperature in Shade by Mercurial Thermometer.	Excess of Blackened Thermometer in the Sunshine.	Temperature in Shade by Mercurial Thermometer.	Excess of Blackened Thermometer in the Sunshine.	Temperature in Shade by Mercurial Thermometer.	Excess of Blackened Thermometer in the Sunshine.	Temperature in Shade by Mercurial Thermometer.	Excess of Blackened Thermometer in the Sunshine.
1	+17°.5	....	+24°.5	....	+28°.2	....	+29°.2	....	+29°.8	....	+28°.5	....	+29°.0	....	+29°.0	....	+29°.0	....	+29°.2	....	+29°.4	....	+28°.5	....
2	22.0	....	24.2	....	26.5	....	28.0	....	28.0	....	28.3	....	28.5	....	29.0	....	27.4	....	25.0	....	23.3	....	22.0	....
3	8.0	....	12.0	....	15.0	....	18.0	...	17.8	....	16.0	....	17.8	....	19.0	....	18.0	....	17.0	....	10.5	....	14.0	....
4	1.5	2°.0	10.0	10.0	13.0	38°.5*	15.0	35°.0	16.0	42°.0	17.2	30°.8	20.0	34°.0	21.0	30°.0	22.0	25°.0	20.0	20°.0	20.5	13°.5	20.0	....
5	23.5	4.0	30.0	17.0	31.5	19.5	32.1	25.9	33.0	38.5	35.0	42.5	33.5	29.5	37.0	34.0	36.0	26.0	35.0	26.5	34.8	21.8	34.6	17°.0
6	32.5	3.0	35.0	37.0	37.0	32.5	39.0	42.0*	40.0	44.0*	42.5	45.5	44.0	49.5*	45.0	43.0	43.0	40.5*	44.0	36.0	43.2	30.8	42.5	27.5
7	33.0	2.5	36.0	37.0	39.0	32.0	37.0	38.5	40.0	41.6	42.8	46.2	43.0	47.0	43.8	43.7*	43.0	38.0	44.0	37.0	45.6	32.0*	44.0	46.0*
8	23.0	1.0	33.0	33.0	32.5	31.3	36.3	30.3	38.0	40.0	36.0	35.0	34.5	32.0	33.0	32.0	36.6	39.0	34.3	38.4*	34.0	28.0	34.3	24.7
9	24.5	0.0	29.0	8.5	30.2	10.8	32.0	12.0	32.0	12.0	33.2	11.8	35.0	20.0	34.0	8.6	34.0	10.5	33.0	11.0	33.0	5.0	34.5	5.5
10	28.0	0.0	29.0	8.0	30.4	14.6	32.5	17.5	34.6	22.9	39.0	29.5	39.2	29.3	40.0	24.0	41.3	25.3	41.2	23.1	40.2	19.8	39.0	10.4
11	17.5	1.0	30.0	33.5	38.0	33.0	39.0	26.0	44.0	28.0	42.0	23.0	45.0	34.0	45.0	28.0	46.0	20.0	43.0	17.0	44.0	20.2	44.0	15.0
12	30.0	2 0	36.0	12.0	38.0	29.0	38.6	38.2	36.5	40.0	36.8	33.2	37.5	46.5	39.0	40.0	40.0	36.5	40.0	32.5	40.0	30.0	40.0	23.7
13	35.5	21.0	39.2	38.8*	41.0	36.0	41.0	33.0	44.0	37.0	46.0	38.0	43.5	24.5	44.0	33.0	41.0	18.5	40.7	18.3	40.0	16.0	40.0	14.5
14	36.0	11.5	42.2	25.0	45.0	30.0	47.2	36.8	47.0	37.0	47.0	37.0	49.0	30.0	48.2	34.3	48.0	36.0	41.7	29.8	42.0	31.0	39.4	29.5
15	9.5	5.0	36.0	17.0	38.0	20.0	36.3	5.0	39.8	29.2	40.0	41.0	40.0	24.0	41.0	39.0	43.0	30.0	40.0	22.0	41.0	21.5	41.0	29.0
16	8.0	22.5*	38.9	13.1	41.0	29.0	43.0	40.0	45.0	40.0	45.0	37.0	47.0	42.0	47.5	37.5	49.5	14.3	49.2	33.8	48.0	31.0	47.0	27.0
17	40.0	12.6	43.0	13.3	43.0	15.0	48.0	36.0	49.5	37.0	51.0	33.0	50.0	39.0	50.1	20.0	51.5	22.5	49.0	13.0	49.0	....	49.0	8.0
18	37.0	2.5	38.3	6.2	37.5	2.5	37.2	4.0	37.0	5.0	36.0	5.0	35.5	8.0	34.0	5.0	35.0	9.0	37.2	2.8	36.6	7.0	36.0	5.0
19	30.8	5.5	35.0	24.0	36.2	29.0	40.0	28.0	44.0	39.0	41.0	31.5	42.0	30.0	39.5	14.5	38.5	16.5	43.0	12.0	42.7	9.7	40.0	3.0
20	29.5	3.0	31.0	8.5	31.5	8.0	32.0	15.0	33.0	17.0	35.0	15.0	35.0	12.0	35.5	12.0	36.0	8.6	36.0	6.0	36.0	4.0	36.0	0.0
21	33.8	10.0	36.0	15.0	38.0	29.5	39.5	37.9	39.0	32.0	39.0	26.0	39.5	28.0	40.0	17.0	40.0	20.0	41.0	20.0	38.5	7.0	39.0	4.0
22	35.0	5.5	38.0	9.0	42.0	18.0	42.0	22.0	46.0	20.0	50.0	13.0	41.4	22.6	48.0	35.0	46.0	37.5	46.0	33.0	46.0	30.0	41.5	19.0
23	35.6	4.0	42.0	8.0	43.0	8.8	44.0	10.0	42.0	12.0	44.0	10.2	43.0	24.0	43.0	22.0	43.0	17.0	44.0	16.5	44.0	25.0	41.0	13.0
24	35.0	12.5	40.0	30.0	40.3	29.0	43.0	25.5	46.2	22.8	50.2	49.8*	50.2	41.0	50.2	32.7	50.3	37.1	50.0	32.0	48.0	29.0	46.0	27.0
25	36.5	6.0	49.0	24.0	50.0	27.0	48.0	29.0	46.0	30.0	44.0	31.0	52.0	29.0	42.0	12.0	52.0	31.0	53.6	17.4	50.4	14.6	41.5	2.5
26	44.0	22.0	47.4	35.6	50.0	28.0	51.0	32.0	52.0	36.0	57.0	39.0	56.0	37.0	52.0	25.0	48.0	14.0	45.6	17.9	53.0	7.0	51.2	2.0
27	42.3	0.0	46.6	9.0	46.6	13.4	49.8	30.0	55.0	34.0	57.0	29.0	57.0	27.0	60.0*	24.5	56.0*	25.0	60.8*	24.0	51.0	29.0	50.4	29.0
28	40.7	4.0	45.0	36.0	45.0	28.0	46.0	32.0	49.0	36.0	52.0	38.0	53.0	29.0	50.0	32.0	47.0	34.0	45.0	31.0	46.5	27.0	48.0	27.0
29	46.0	2.0	48.0	12.0	50.0	20.0	54.0*	19.8	57.0*	27.5	57.5*	26.5	57.3*	26.7	56.2	16.0	55.2	6.8	55.7	5.0	56.0*	3.0	53.0*	1.5
30	41.8	6.5	48.5	29.5	43.0	23.0	46.0	20.0	48.0	28.2	46.0	32.0	48.0	31.0	52.0	32.0	47.0	17.0	45.0	9.0	46.0	9.0	44.0	6.4
31	55.7*	5.5	58.8*	21.7	61.0*	32.0	45.0	23.0	46.0	14.0	49.2	31.3	47.2	17.8	43.2	8.8	47.0	8.0	47.0	6.8	47.0	6.0	42.0	3.0

Time of maximum force of Solar Radiation.

(279.) The means of the successive columns of this valuable Table are recorded in that which next follows; and it appears from a comparison of the different numerical results, that the force of Solar Radiation is at its maximum when the Sun is on the meridian, but that the greatest temperature in the shade occurs an hour later. The Solar Radiation increases also from the morning to noon, and declines from noon to the evening.

TABLE LIX.

Month.	Hour.	Mean Temperature in the Shade by a Mercurial Thermometer.	Mean Excess of a Blackened Mercurial Thermometer in the Sunshine.
May.	A.M. 5	31°.79	6°.33
	8	36.86	20.41
	9	38.10	23.83
	10	39.02	26.58
	11	40.47	30.09
	Noon	41.42	30.75
	P.M. 1	41.73	30.15
	2	41.65	26.27
	3	41.61	23.70
	4	41.17	21.14
	5	40.59	18.14
	6	39.45	15.56

Graphical illustration of the power of Solar Radiation in the Polar regions and in London.

(280.) By contrasting also the last Table with the horary observations of Mr. Daniell, given in Table XLIX., we shall arrive at some other useful results. To enable us to make this comparison more readily, we have in some degree anticipated a subject into which we shall hereafter enter more fully, the method of exhibiting the alterations of atmospheric phenomena by means of graphical illustrations. For this purpose fig. 4 has been constructed from the Tables last quoted. The horizontal line A B in the diagram is divided so as to represent the times at which the observations were made; and the vertical lines springing from it represent the mean temperatures in the shade, and the effects of the solar radiation. Hence the curve E F denotes the mean temperature in the shade as recorded in Table LIX., and the still more irregular and dotted line C D the measure of the Solar Radiation. The nearly uniform line I K also in the diagram, denotes the temperature in the shade, as registered in Table XLIX., and the towering dotted curve G H represents, in like manner, the unequal and varied effects of the Sun's radiating power. The maximum temperature of the air in the shade for each hour during the month is denoted by the line L M, and the greatest power of the Solar Radiation for the same hours, by the dotted line N O.

Remarks relating to this comparison,

(281.) There is one thing, however, which we must mention with regard to this comparison, and that is, the curves for the Polar regions have been constructed for the means of an entire month, whereas those representing the labours of Mr. Daniell are confined to a single day. At the same time we must also bear in mind, that one system of results belongs to May and the other to June. Such are the limited materials we have to work with, that we can offer no better method of comparison.

and to tl aspect ol the grap cal curv

(282.) If we consider for a moment these different curves, one of the most obvious results is, that the power of Solar Radiation in the temperate and frigid zones is by no means the same. In the former region it would seem as if the Solar power was much more capricious in its changes, than in the colder regions of the North. The horary changes are much more rapid, and the entire aspects of the curves are different.

Dr. Ri- chardsoı remarks lative to intensity Solar Ri tion.

(283.) Dr. Richardson remarks, that the intensity of the Solar Radiation shown by the blackened thermometer was generally greatest when the sky was of a deep blue colour, and it was not much affected by scattered clouds, however dense, unless they passed over the face of the Sun. The temperature produced by the Sun's rays (except when the exposed thermometer was cooled by Southerly winds) generally increased, as might have been expected, gradually from sunrise to noon, and decreased again to sunset, but on an average the radiation was found to be more powerful in the forenoon, than at corresponding altitudes of the Sun in the afternoon. Dr. Richardson also found the radiation to be much stronger in the Spring months when the ground was covered with snow, than in the summer months when the altitude of the Sun was greater.

Intensit at equal titudes pendent the clea ness of atmosph

(284.) The difference of intensity of the Solar Radiation at equal altitudes of the Sun is, Dr. Richardson imagines, dependent upon variations in the clearness of the atmosphere; and, perhaps, the greater transparency of the air in the Spring, before the snow disappears, may, as he conceives, be explained somewhat as follows. In the month of March, for example, the Sun in the latitude of Port Franklin has sufficient power to heat the atmosphere considerably; but the snow then lies unmelted on the ground, and the temperature sinks very low in the night, frequently as low as it does at any time during the winter. Hence the cold, during the night, causes much of the moisture of the atmosphere to be deposited in the form of hoar frost; whilst, on the other hand, the warmth which the air acquires after sunrise renders its solvent power greater than the slow evaporation from snow, cooled most frequently below zero, can satisfy. The consequence is, that all the haze or mist floating in the air is completely dissolved shortly after sunrise, and the sky becomes clear to a degree which is unknown there in the summer, or in any season in more Southerly latitudes. The greater haziness of the sky after the Sun has passed the meridian, probably depends in some degree on the currents of air produced by the heat of the Sun, mingling portions of the atmosphere at different temperatures.

Solar R tion gr when p tial th clouds vailed.

(285.) During the summer, the power of the Sun was perceived to be the greatest, when partial thunder-clouds were floating over a deep blue sky, and after a few large drops of rain had fallen. When the Sun shone out at such times, its heat, Dr. Richardson remarks, was very oppressive.

Conne with re tion.

(286.) The highest peak of a chain of hills, distant about forty miles from Bear Lake, was visible in clear weather; and in particular states of the atmosphere a considerable portion of the range was seen, so that the amount of refraction of the air was in some degree indicated by the extent of hill that appeared over the low intervening grounds. The refraction measured in this way was greatest in a clear sky, when the temperature had been very low in the night, but was rising rapidly in the day, evidently through the influence of Solar Radiation.

(287.) The whole of Mr. Daniell's inquiries led him to the conclusion, that the power of Solar Radiation in the atmosphere increases from the Equator to the Poles. This opinion of Mr. Daniell has not been without its opponents. In the *Annales de Chimie* for August 1824, the accuracy of the experiments on which it is grounded, has been questioned. It has been urged that the thermometers were influenced by the vegetation on which they rested, that they were not always placed at equal distances from the ground and from the vegetation which covered it, nor were they equally secured from the action of currents of air. Mr. Daniell, in his reply to these objections in the XVIIIth volume of the *Journal* of the Royal Institution, observes that there is ample room for allowances of this kind, and yet to save the conclusion, that the power of Solar Radiation is less between the tropics than in higher latitudes.

Objections to Mr. Daniell's conclusion that solar radiation increases from the Equator to the Poles, in the Annales de Chimie.

(288.) Mr. Foggo in adverting to the same subject, in the XXVIIth number of the *Edinburgh Philosophical Journal*, is of opinion, that Mr. Daniell has confounded the actual power of the Sun's rays with the excess of temperature indicated by a thermometer exposed to the Sun above the temperature of the air, and that the situations of the thermometers of observation were not free from objection. Captain Sabine's thermometer with a blackened bulb, and covered with black wool, when placed on *grass*, did not, Mr. Foggo thinks, present the full measure of the solar influence in the experiments at Bahia. In support of this opinion, he adduces some experiments of his own, performed near Edinburgh, on the 7th of July. On a part of that day, when the temperature of the air was 59°, with a brisk wind, he exposed a large thermometer, having its ball covered with black wool, to the direct rays of the Sun, but unsheltered from the wind. On exposing the instrument to the direct action of the Sun, it rose to 95° in ten minutes. By laying it horizontally on short grass, it fell to 60°; but on restoring it to its former situation, it again rose to 94°. On the 29th of the same month, at $3^h\ 10'$ P. M., the same thermometer, which had been exposed all day in a sheltered corner, rose to 150°; when another instrument, similarly prepared, and resting in contact with the herbage, indicated only 119°. On the same day at two P. M. the former thermometer indicated 140°, and the latter 110°. Mr. Foggo, therefore, remarks, that we have here a difference of 30°, arising solely from the manner in which the instruments were exposed.

Mr. Foggo's objections.

His experiments.

(289.) These experiments are, however, too few in number to ground any hypothesis on; but they, nevertheless, open some room for supposing that, in the observatoins performed in the tropical regions, the full measure of the solar influence was not obtained; and we have indirect evidence from other quarters to strengthen such a view. Many detached observations exist in the writings of different travellers respecting the heat measured with *naked* thermometers, which seem to indicate a much higher measure of the solar influence. In Caffraria, Mr. Barrow saw an exposed thermometer mark 106°. The missionary Campbell, during his interesting journey in the winter through the Country of the Botchuanas, when the air at eight A. M. was 28°, saw the thermometer in the sun at noon rise to 84°. At Gondar, Mr. Bruce mentions a temperature of 113°; while at Benares 110°, 113°, and 118° respectively are recorded.

Tropical observations

(290.) Other detached observations respecting the temperature of the Earth, where it has been fully exposed to the effects of insolation, tend also to strengthen the supposition that the Solar Radiation is greater in the tropical regions than the observations of Captain Sabine would seem to indicate. At Sierra Leone, Dr. Winterbottom saw a thermometer placed on the ground rise to 138°. Humboldt also gives many instances of the temperature of the Earth amounting to 118°, 120°, and 129°; and at one time he found the temperature of a loose and coarse-grained granitic sand 140°.5; another, finer and more dense, 126°, the thermometer in the sun being at the same time 97°.16. It is probable, remarks the distinguished traveller, that the mean temperature of the dried mud, in which the alligators bury themselves during their state of periodical torpor, is more than 104° Fahrenheit.

Temperature of the Earth fully exposed to insolation.

(291.) Mr. Daniell is also of opinion, from some experiments performed by Captain Sabine on the mountains of Jamaica, and also from some observations made by Saussure, in his *Voyage dans les Alpes*, that the power of Solar Radiation increases from the surface of the Earth upwards.

Solar radiation increases upwards.

(292.) In the absence of positive experiments performed on a much more extended scale than we possess at present, it would be a departure from the rules of Philosophic prudence to adopt any hypothesis whatever. There are too many conditions involved; the range of observation is too wide, spreading out as it does from the Equator to the Poles; the circumstances of climate are too diversified; too little, indeed, is known concerning the force of Solar Radiation in those Countries most favoured by the presence of men devoted to the advancement of Meteorological knowledge, to justify the adoption of any theory to represent its varying conditions in other latitudes.

Concluding remarks.

Terrestrial Radiation.

(293.) It is a beautiful discovery of our own times, that if two bodies of different temperatures are placed at a certain distance from each other, even in a vacuum, that the one whose temperature is the highest, will gradually communicate its caloric to the other. In our Essay on HEAT we have unfolded some of the leading phenomena connected with this interesting inquiry, and we shall, therefore, only add such observations as will enable us to disclose its relations to Terrestrial Radiation.

Introductory remarks.

(294.) Since every portion of the Earth's surface incessantly loses heat by radiation, let us suppose that a small body, whose surface radiates freely, is placed beneath a clear and tranquil sky, on a vast uncovered plane. Such a body will emit calorific rays towards every point of the visible heavens, and unless it can receive heat in return from the upper sky, which (in the portion of this Essay devoted to Dew will be proved not to be possible in the case under consideration,) a body circumstanced like that in our hypothesis will undoubtedly be cooled. Applying this reasoning to the Earth's surface generally, when not exposed to the direct action of the sun, to the plains and the valleys, the mountains with all their varieties of surface and all their diversities of radiating power, and we shall recognise

Supposition of a good radiator being placed beneath a clear and tranquil sky.

Application to the Earth's surface generally.

an active and powerful principle, tending under some circumstances to cool the atmospheric strata in contact with it.

Inquiries of Dr. Wells.

(295.) The experiments of Dr. Wells which relate to the subject now under consideration, were directed in a great measure to establish the important fact, that a thermometer placed on the ground beneath a clear and tranquil sky, will exhibit a lower temperature than one suspended freely in the air. The clear and convincing experiments by which he established this important principle will be shown in the portion of our Essay just referred to. It was no part, however, of his inquiry to estimate the force of Terrestrial Radiation through the successive months of the year, and to communicate those general views which the later labours of Mr. Daniell have so successfully disclosed. We shall hereafter see that the laborious inquiries with which Dr. Wells was occupied, were sufficient, considering his health, to occupy all the energies of a single mind.

Of Mr. Daniell.

(296.) Mr. Daniell devoted considerable attention to the subject of Terrestrial Radiation, and in the following Table will be found the mean effect of radiation for every month, deduced from the averages of three successive years, together with its greatest observed intensity in the same intervals.

TABLE LX.

Months.	Mean Minimum of the Air.	Mean Depression from Radiation.	Maximum Depression from Radiation.
January	32°.6	3°.5	10°
February	33.7	4.7	10
March	37.7	5.5	10
April....	42.2	6.2	14
May	45.1	4.2	13
June...............	48.1	5.2	17
July	52.2	3.6	13
August.............	52.9	5.2	12
September..........	50.1	5.4	13
October	42.1	4.8	11
November	38.3	3.6	10
December...........	35.4	3.5	11

Analogy of his results with the law of radiation of Dulong and Petit.

(297.) The last column of the Table seems to indicate an approximation to the law of radiation established by Dulong and Petit, that the velocity of cooling *in vacuo*, or the force of radiation, increases as the terms of a geometrical progression for increments of temperature in arithmetical progression. The force of radiation as developed in the Table, has manifestly a tendency to increase with the heat, although the effect is concealed by too many disturbing causes to enable us to determine the law of the progression. From the third column we may also form an estimate of the clearness of the atmosphere, and the comparative brightness of the different months. April appears to be the clearest month of the year, and the cloudy state of July is deserving notice.

Important inferences of Mr. Daniell.

(298.) Mr. Daniell infers from his diary, that for ten months in the year in our climate, vegetation is liable to be affected at night, from the influence of radiation, by a temperature below that of the freezing point; and that even in the months of July and August, the radiant thermometer sometimes falls to 35°.

Comparative experiment of Captain Sabine at Bahia and Jamaica.

(299.) Captain Sabine performed also a number of comparative experiments on the same subject, in the tropical regions. At Bahia and Jamaica, he exposed upon grass to the aspect of the sky an alcohol thermometer, registering the extreme cold, and having its bulb covered with black wool. The following Tables contain a comparison of its indications with those of a register thermometer placed under shelter.

TABLE LXI.—*For Bahia.*

Day.	Temperature of Air.	Temperature of Radiation.	Difference.	Observations.
July 24	68°	63°.5	4°.5	Dew.
25	68	63.5	4.5	Dew.
26	72	62.5	9.5	Dew.
27	70	61.0	9.0	Dew.
28	64	60.5	3.5	
29	67	59.5	7.5	
30	65	64.0	1.0	

(300.) Captain Sabine remarks, that the register of the cold was the same, whether the thermometer was placed on a grass plat, or on a thick bed of rotboëlia, or on thick tufts of poa—a curious and valuable remark connected with the radiating powers of vegetables.

TABLE LXII.—*For Jamaica.*

Day.	Temperature of Air.	Temperature of Radiation.	Difference.
October 25	76°	72°	4°
26	76	69	7
27	76	65	11
28	76	66	10
29	76.5	65	11.5
30	76	65	11
November 3	76	67	9

(301.) Upon the mountains of Jamaica, 4000 feet above the level of the sea, Captain Sabine found the thermometer laid upon grass to afford the following results.

TABLE LXIII.

Date.	Time.	Temperature of Air.	Temperature of Radiation.	Difference.	Observations.
Oct. 31	P. M. 10h	65°	51°	14°	Clear and calm.
Nov. 1	A. M. 5	63	45	18	Ditto.
	P. M. 11	64	51	13	Clear and gentle breezes.
2	A. M. 5	64	55	9	Ditto.

(302.) From all these experiments, Mr. Daniell

Mr. Daniell's inferences.

infers that the same cause which obstructs the passage of radiant heat in the atmosphere from the Sun, opposes also its transmission from the Earth into space; and that the force of radiation for a given temperature, is less between the tropics than in the latitude of London, and that it obviously increases as we ascend above the Earth.

Objections made in the *Annales de Chimie.*

(303.) In the *Annales de Chimie* some remarks have been made, tending to prove that the results belonging to the tropical regions were obtained at times when the air was less clear or calm than at London, but there seems no reasonable ground for such a supposition. There are two circumstances, as Mr. Foggo justly remarks, which are sufficient of themselves to explain the anomaly:—first, the high temperature of the soil, which, in the torrid zone, frequently retains a heat of several degrees above that of the air, even when the latter has reached its minimum; and, secondly, the law established by Mr. Anderson, that the minimum temperature of the night is regulated by the constituent temperature of the aqueous atmosphere; the great quantity of moisture in the air equally preventing the diminution of its temperature beyond a certain degree, and checking the cooling of the ground by evaporation.

Remarks of Mr. Foggo.

Mr. Daniell's inference of an increase in Terrestrial Radiation as we go North.

(304.) Very little is yet known respecting the force of Terrestrial Radiation in the Polar regions. Mr. Daniell imagines from the intense cold which was found to prevail during calm weather in Melville Island, that a strong argument may be derived in favour of an increase of the radiating power as we go North. He also infers from the following remark by Mr. Scoresby, that the power of Terrestrial Radiation is developed in a very powerful degree.

Mr. Scoresby's remarks tending to the same point.

(305.) In cloudy weather, observes Mr. Scoresby, no freezing of the sea ever occurs when the temperature is above 29°; but in clear, calm weather, the sea, in the interstices of the ice, generally freezes on the decline of the Sun towards the meridian below the Pole, though the temperature be 32°, or higher. In the instance now alluded to, the freezing commenced when the temperature was 36°, being 7½° or 8° above the freezing point of sea-water. About two A. M. the thermometer in the air fell to 33°, by which time the bay ice was of such consistence, that the head-way of the ship, under a light breeze, was sometimes stopped by it.

The effects of radiation vary with the aspect of the sky.

Dr. Wollaston.

Mr. Leslie.

(306.) These effects of radiation vary with the aspects of the sky, operating vertically and in every oblique direction. Dr. Wollaston was the first to attempt to measure the effect, when a metallic mirror was presented to the upper sky; and we shall hereafter see, in the portion of our Essay devoted to Meteorological Instruments, that Mr. Leslie contrived his Æthrioscope to enable us to estimate the effects at intermediate altitudes.

Mr. Daniell's researches on the same subject.

(307.) Mr. Daniell, in estimating the effects of radiation under different aspects of the sky, employed the apparatus of Wollaston. The standard thermometer to which all his observations were referred, when not otherwise expressed, had its bulb covered with black wool. Another thermometer was placed upon the grass. The next Table exhibits a series of his interesting results relating to the force of radiation in a reflector and on the grass.

TABLE LXIV.

	Temperature of Air.	Temperature of Grass.	Temperature in Reflector.	Observations.
	42°	34°	30°	Very fine and clear.
	47	39	35	Ditto.
	52	44	42	Ditto.
	44	35	32	Ditto.
	44	36	34	Ditto.
	54	48	45	Ditto.
	58	52	52	Dull.
	57	51	49	Very fine. Moon hazy.
	56	51	50	Light clouds.
	51	41	41	Very fine and clear.
	45	35	35	Ditto.
	50	42	41	Ditto.
Means	50	42.3	40.5	

Mr. Daniell's comparison of effects when the Sun is above and below the horizon.

Effect of colour.

(308.) Mr. Daniell's next attempt was, by means of the same apparatus, to compare the force of radiation when the Sun is above the horizon, with its power when that luminary is below. Under the most favourable circumstances, in a clear and tranquil atmosphere, he could never obtain an effect of more than five or six degrees with the thermometer covered with black wool. Imagining, however, that *colour* might in some degree modify the results, he had another reflector constructed precisely similar to the former, the radiating thermometer falling to an equal amount in each. In the focus of one of these reflectors he placed a thermometer, having its bulb covered with white wool, and in the focus of the other another thermometer, having its ball covered with black wool. A cloudless day was selected for the experiment, and the two instruments, placed side by side, were inclined at equal angles towards the Eastern sky. The following Table contains the results.

TABLE LXV.

Day.	Hour.	Radiation from Black Wool.	Radiation from White Wool.	Temperature of Air.	Observations.
May 16	P. M. 3½h	58°	53°	63°	Cloudless. During the experiment the reflectors were changed.
	4	58	53	63	
	8	44	43	54	
	11	36	36	47	
	During night	35	35	45	

Inference.

(309.) Hence it appears, that the amount of radiation from the white wool was equal, during the time the Sun was high in the heavens, to what it was during the night; while it was one half less from the black wool. During the absence of the Sun, the radiating power of the two was the same.

Other experiments.

(310.) Mr. Daniell repeated these interesting experiments under many varieties of circumstances; and in examining his results contained in the following Table, it is especially necessary to attend to the collateral circumstances.

TABLE LXVI.

Day.	Hour.	Radiation from Black Wool.	Radiation from White Wool.	Temperature of the Air.	Observations.
May 17	P.M. 1½h	64°	59°	65°	Overcast, with cumulo stratus.
	2	68	60	65	Clearing—reflectors to clearing space.
	2½	73	62	65	Faint sunshine.
	3½	74	62	66	Strong sunshine—reflectors turned, so that the shadows of the bulbs just appeared on the metal.
	4	76	64	68	
	11	51	51	55	Lightly overcast.
	Night.	42	42	51	Fine.

Remarks on the preceding Table.

(311.) On this Table Mr. Daniell makes the following remarks. The power of radiation was nearly neutralized in the black wool while the sky was overcast, but in the white wool it was only reduced to about one half. As the sky cleared, the reflectors being turned towards the Sun's place, the black thermometer rose above the temperature of the air, and the white thermometer still gave off more heat than it received. Exposed to the full power of the Sun, the reflectors being just turned out of the direct rays, the black thermometer rose 8° above the temperature of the air, and the white thermometer fell 4° below it. In estimating these different effects, it must be remembered, that the action of the reflector, in receiving and transmitting heat, is different. In the former case, the action is unduely increased, the heat which falls upon the surface of the speculum being thrown upon the thermometer in a concentrated form. In the latter case, the heat which radiates from the thermometer in the focus falls upon the concave metal, and is reflected into space in parallel lines. The effect is, therefore, only slightly augmented from the larger aspect of the sky. Mr. Daniell also found, whenever the reflector with the black woolled thermometer was turned towards a cloud, during the presence of the Sun above the horizon, that the mercury rose above the temperature of the air, excepting in the winter months; and a visible effect was produced even from the quarter most distant from the Sun. The concrete vapour, Mr. Daniell thinks, disperses the radiant matter, and acts upon it much in the way that ground glass operates upon transmitted light. No effect is produced by any cloud after the Sun has sunk below the horizon; and in an overcast night the action of radiation is perfectly neutralized. The following Table tends to illustrate this point; and to show the effects of two similar thermometers placed in the foci of similar reflectors, directed to different quarters of the heavens.

Action of the reflectors.

Effect of a cloud.

No effect after the Sun is below the horizon.

Experiment to illustrate it.

TABLE LXVII.

Date.	Hour.	Position of the Reflector.	Temperature of Black Wool.	Temperature of Air.	Observations.
July 2	Noon.	Horizontal inclined 30°.	76° 79	63°	Sky overcast—Cumulo stratus—Sun's place not visible—and brisk wind S.W.
	1 P.M.	Horizontal inclined 30°.	83 83	63	Sun's place just visible, but no shadows.
	2	Horizontal inclined 30°.	86 86	63	Ditto.
	2½	Horizontal inclined 30° E.	83 82	63	Sun's place not visible.
	3	Horizontal inclined 30° N.	79 79	63	Ditto.
		Inclined 30° N. 30° S.	76 79	63	Ditto.
		Inclined 30° N. E. 30° S. W.	85 88	63	Ditto.
	3½	Inclined 30° N. E. 30° S. W.	96 100	63	
		Inclined W. E.	55 55	61	Just before sunset.
	11	Inclined N. S.	57 57	61	
	Night.	Inclined N. E.	40 40	48	Fine.
4	All Night.	Horizontal Vertical	41 43	51	Very fine.

Concluding remarks.

(312.) We commenced this division of our Essay by stating, that we owe to Mr. Daniell nearly all the information we possess on this very interesting subject; and being anxious to lay before our readers all that we are able to obtain, we draw from the same respectable source the following Table by way of conclusion, to denote the results obtained by a black radiating thermometer in a concave reflector, turned to the North, at an angle of 30°.

Table LXVIII.—*Observations of a Black Radiating Thermometer, in a Concave Reflector, turned to the North, angle 30°.*

Date. 1822.	Hour.	Temp. of Air.	Day.	Night.	Difference.	State of Reflector.	State of Weather.
Jan. 13	P. M. 4	48	45	..	− 3	....	Fine but misty.
	11	45	..	37	− 8	....	Ditto.
	Night.	40	..	32	− 8	....	Very fine.
14	A. M. 10	42	35	..	− 7	Spots of rain.	Very fine and clear.
	P. M. 4	42	35	..	− 7	....	Cloudless.
	11	39	..	30	− 9	....	Light clouds.
	Night.	40	..	36	− 4	....	Ditto.
15	A. M. 9	40	32	..	− 8	Bright.	Very clear.
	P. M. 11	31	..	21	−10	....	Ditto.
	Night.	30	..	20	−10	Bright.	Ditto.
16	A. M. 9	31	22	..	− 9	....	Ditto.
	P. M. 4	31	21	..	−10	....	Ditto.
	11	29	..	19	−10	....	Ditto.
	Night.	29	..	19	−10	....	Ditto.
17	A. M. 9	33	33	..	0	....	Snow.
	P. M. 11	33	..	26	− 7	....	Very fine.
	Night.	32	..	25	− 7	....	Ditto.
18	A. M. 9	35	30	..	− 5	Bright.	Ditto. Misty.
	P. M. 4	39	34	..	− 5	....	Ditto.
	11	39	..	37	− 2	....	Overcast and dull.
	Night.	38	..	33	− 5	....	Dull.
19	A. M. 9	41	41	..	0	Tarnished.	Dull and foggy.
26	A. M. 9	40	32	..	− 8	....	Very fine.
	P. M. 11	40	..	35	− 5	....	Dull.
	Night.	32	..	22	−10	Dull and spotted.	Very fine.
27	A. M. 10	34	27	..	− 7	....	Ditto.
	P. M. 4	47	47	..	0	....	Overcast and dull.
	11	40	..	40	0	....	Ditto.
	Night.	35	..	33	− 2	....	Dull.
28	A. M. 9	45	43	..	− 2	Spotted with rain.	Mild and misty.
	P. M. 11	41	..	39	− 2	....	Overcast and dull.
	Night.	35	..	27	− 8	....	Very fine but misty.
29	A. M. 9	37	31	..	− 6	Blacks in the mirror.	Ditto.
	P. M. 11	38	..	34	− 4	....	Lightly overcast.
	Night.	32	..	22	−10	....	Very fine.
30	A. M. 9	34	26	..	− 8	....	Ditto.
	P. M. 11	34	..	30	− 4	....	Fog.
	Night.	30	..	23	− 7	....	Fine.
31	A. M. 9	35	33	..	− 2	Dew upon lower half.	Light clouds.
	P. M. 11	35	..	28	− 7	....	Drops of rain.
	Night.	35	..	28	− 7	....	Fine.
Feb. 1	A. M. 9	42	37	..	− 5	Spotted with rain.	Very fine.
	P. M. 11	38	..	29	− 9	....	Ditto.
2	A. M. 9	47	47	..	0	Tarnished and spotted.	Small rain.
	P. M. 11	49	..	45	− 4	....	Fine.
	Night.	39	..	39	0	Full of rain.	Rain.
3	A. M. 10	44	39	..	− 5	....	Very fine.
	P. M. 11	37	..	28	− 9	....	Ditto.
	Night.	33	..	25	− 8	....	Ditto.
4	A. M. 9	38	36	..	− 2	Moisture running off the bulb.	Foggy.
	P. M. 11	47	..	45	− 2	....	Overcast.
	Night.	38	..	37	− 1	....	Stormy.
5	A. M. 10	49	42	..	− 7	....	Fine.
	P. M. 11	39	..	30	− 9	....	Very fine.
	Night.	32	..	22	−10	Hoar-frost upon the bulb and stem.	Ditto.
6	A. M. 10	35	27	..	− 8	....	Ditto.
	P. M. 11½	41	..	35	− 6	....	Dull and close.
7	A. M. 9	45	43	..	− 2	Tarnished.	Ditto.
	P. M. 3	48	45	..	− 3	....	Ditto.
	11	47	..	43	− 4	....	Ditto.
	Night.	45	..	41	− 4	Full of rain.	Ditto.
8	A. M. 9	48	45	..	− 3	....	Overcast but fine.
	P. M. 11	45	..	42	− 3	....	Ditto.
	Night.	42	..	36	− 6	Spotted with rain.	Ditto.
9	A. M. 10	47	47	47	0	....	Overcast and mild.
	P. M. 11	49	..	47	− 2	....	Ditto.
	Night.	46	..	41	− 5	....	Ditto.
10	A. M. 10	47	45	..	− 2	....	Ditto.
	P. M. 11	47	..	45	− 2	....	Light rain.
	Night.	41	..	33	− 8	Spotted with rain.	Very fine.
11	A. M. 10	44	41	..	− 3	....	Ditto.
12	P. M. 11	39	..	36	− 3	Stained.	Fog.
	Night.	37	..	33	− 4	Some water.	Ditto.
13	A. M. 9	41	38	..	− 3	....	Fine but misty.
	P. M. 4	44	38	..	− 6	....	Ditto.
	Night.	40	..	32	− 8	....	Very fine.
24	A. M. 10	46	48	..	+ 2	....	Lightly overcast.
	P. M. 11	48	..	46	− 2	....	Overcast and dull.
	Night.	46	..	43	− 3	....	Ditto.
Feb. 25	A. M. 10	51	55	..	+ 4	....	Lightly overcast.
	P. M. 11	47	..	43	− 4	....	Ditto.
	Night.	44	..	39	− 5	Bright.	Ditto.
26	A. M. 10	49	53	..	+ 4	....	Ditto.
	P. M. 4	51	54	..	+ 3	....	Overcast, rain.
	11	45	..	41	− 4	....	Clearing.
	Night.	36	..	26	−10	Spotted with rain.	Very fine.
27	A. M. 10	42	34	..	− 8	....	Ditto.
	P. M. 11	35	..	24	−11	....	Ditto.
	Night.	31	..	22	− 9	Hoar-frost on bulb.	Ditto.
28	A. M. 10	34	30	..	− 4	....	Ditto. Fog.
	P. M. 5	43	37	..	− 6	....	Ditto.
	11	35	..	26	− 9	....	Ditto.
	Night.	30	..	20	−10	Hoar-frost on bulb.	Ditto.
Mar. 1	A. M. 10	34	31	..	− 3	....	Ditto. Fog.
	P. M. 11	39	..	33	− 6	....	Light clouds.
	Night.	34	..	31	− 3	....	Ditto.
2	A. M. 10	46	47	..	+ 1	....	Overcast and mild.
	P. M. 11	43	..	36	− 7	....	Very fine.
11	P. M. 4	46	50	..	+ 4	....	Turned to a dense cloud.
	5	44	40	..	− 4	....	Very fine.
	11	37	..	28	− 9	....	Ditto.
14	A. M. 10	54	60	..	+ 6	....	Overcast and dull.
19	A. M. 10	56	61	..	+ 5	....	Lightly overcast.
	5	59	57	..	− 2	....	Ditto.
	11	54	..	51	− 3	....	Ditto.
	Night.	51	..	46	− 5	....	Fine.
20	A. M. 10	54	58	..	+ 4	....	Lightly overcast.
	P. M. 5	56	50	..	− 6	....	Very fine.
	Night.	46	..	37	− 9	....	Ditto.
21	A. M. 10	51	52	..	+ 1	....	Overcast.
	P. M. 5	56	51	..	− 5	....	Very fine.
	11	51	..	49	− 2	....	Overcast.
	Night.	41	..	31	−10	....	Very fine.
27	A. M. 10	52	57	..	+ 5	....	Overcast.
	P. M. 5	56	49	..	− 7	....	Very fine.
	Night.	46	..	37	− 9	....	Ditto.
April 1	A. M. 10	42	44	..	+ 2	....	Dense clouds.
	P. M. 5	46	46	..	0	....	Overcast and dull.
	11	42	..	32	−10	....	Very fine.
	11½	43	..	39	− 4	....	Lightly overcast.
	Night.	39	..	31	− 8	....	Fine.
3	A. M. 10	50	59	..	+ 9	....	Lightly overcast.
	P. M. 1	54	60	..	+ 6	....	Ditto.
	2	53	61	..	+ 8	....	Ditto.
	3	53	50	..	− 3	....	Clear.
	5	50	42	..	− 8	....	Very fine.
	11	43	..	35	− 8	....	Ditto.
	Night.	40	..	31	− 9	....	Ditto.
4	A. M. 10	49	58	..	+ 9	....	Lightly overcast.
	10½	51	61	..	+10	....	Ditto.
	11	51	62	..	+11	....	Ditto.
	12	51	60	..	+ 9	....	Ditto. Drops of rain.
	P. M. ½	52	64	..	+12	....	Ditto,
	1	52	58	..	+ 6	....	Ditto.
	3½	51	53	..	+ 2	....	Clearing.
	5	49	47	..	− 2	....	Ditto.
	11	47	..	42	− 5	....	Overcast.
	Night.	43	..	34	− 9	....	Fine.
5	A. M. 10	51	62	..	+11	....	Lightly overcast.
	P. M. 5	51	50	..	− 1	....	Ditto.
	11	46	..	37	− 9	....	Very fine.
	Night.	43	..	33	−10	....	Ditto.
6	A. M. 10	52	52	..	0	....	Ditto.
	P. M. 5	49	49	..	0	....	Ditto.
	11	41	..	31	−10	....	Ditto.
	Night.	39	..	30	− 9	....	Ditto.
7	A. M. 10	45	51	..	+ 6	....	Overcast.
	Night.	36	..	27	− 9	....	Very fine.
8	A. M. 10	45	46	..	+ 1	....	Ditto.
	P. M. 5	39	39	..	0	....	Hail showers.
	Night.	35	..	30	− 5	....	Fine.
15	A. M. 10	57	67	..	+10	....	Lightly overcast.
16	P. M. 5	54	53	..	− 1	....	Dull.
	11	46	..	37	− 9	....	Very fine.
	Night.	41	..	34	− 7	....	Foggy.
28	A. M. 10	56	67	..	+11	....	Very hazy.
	Night.	46	..	40	− 6	....	Fine.

On the Gradation of Heat in the Atmosphere.

Dalton's discovery that increased capacity of air is cause of cold of upper regions.

(313.) We owe to Mr. Dalton the discovery, that the natural condition of the equilibrium of heat in an atmosphere is found, when each atom of air in the same perpendicular column is possessed of the same quantity of heat; and, consequently, that such an equilibrium results, when the temperature gradually diminishes in ascending. This indeed is the natural consequence of the increased capacity for heat derived from rarefaction. When the quantity of heat is limited, the temperature is governed by the density. We shall hereafter refer to the delicate experiments and formulæ by which Professor Leslie determined the law of the progression.

Essential difference between cold from this cause and that arising from radiation.

(314.) There is an essential difference between that decrease of temperature which arises from the increased capacity of air for heat, and the cooling of the atmosphere produced by radiation. The amount of the former is governed by the altitude, and is a constituent element of the density due to the elevation; but by the exercise of the latter, the air is cooled below its natural standard, and thus becomes specifically heavier in its successive strata. From the unequal action of the Sun's rays, says Professor Leslie,[*] and the vicissitudes of day and night, a perpetual and quick circulation is maintained between the lower and upper strata; and for each portion of air which rises from the surface, an equal and corresponding portion must also descend. But that which ascends, acquiring an enlargement of capacity, has its temperature proportionally diminished, while the correlative mass, descending, carries likewise its heat along with it, and, by contracting its capacity, seems to diffuse warmth below. A stratum at any given height in the atmosphere is hence alike affected by the passage of air from below, and by the return of air from above, the former absorbing heat, and the latter evolving it. But the mean temperature at any height in the atmosphere is still on the whole permanent; and, consequently, those disturbing causes must be exactly balanced, or the absolute measure of heat is really the same at all elevations, suffering merely some external modification from the difference of capacity in the fluid with which it has combined. Hence that temperature is inversely as the capacity of air possessing the rarity due to the given elevation.

Knowledg of the gra dation of heat in th atmosphei obtained from the mensurati of heights

(315.) All our knowledge respecting the gradation of heat in the atmosphere, as resulting from the varied causes which operate upon it, has been derived from the useful observations that have been made with the barometer and thermometer, for determining the mensuration of heights; and the exactness of such measurements, within certain limits, cannot be questioned, because they have been verified in so many instances, by the nicest operations of Geometry, and the most delicate and refined operations of levelling. The numerous and diversified theoretical investigations which have been made respecting the beautiful problem of the terrestrial refractions, have also tended in no inconsiderable degree to throw a light on this important inquiry.[†]

Suppositi that the temperatu of a colu of air dim nishes wi the altitu

(316.) If we admit the temperature of a column of air to diminish in the same ratio as the altitude increases, and also suppose the rate of decrease, or the elevation necessary for depressing the thermometer a single degree, to be known, we shall be enabled to deduce with ease and facility the temperature at any altitude in the atmosphere, from the temperature observed at the Earth's surface, and also to compute the height of a column of air, by knowing the temperatures at its extremities. To determine the decrement of temperature, recourse must be had to actual observation.

Observed anomalie

A reference to the best authorities, however, is sometimes productive of considerable anomalies, even in circumstances where it is impossible to discern any cause for an apparent difference. In the following Table are forty-two measurements, taken from the *Mémoires sur la Formule Barométrique de la Mécanique Céleste*, by M. Ramond, made in circumstances of a very varied kind, and free from suspicion of errors of any considerable magnitude. Four of these, however, marked with an asterisk, deviate so widely from the rest, they may with propriety be omitted in estimating the mean.

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[*] Leslie on the Relations of Air to Heat and Moisture.

[†] *La constitution de l'atmosphère étant comprise entre les deux limites d'une densité décroissante en progression arithmétique, et d'une densité décroissante en progression géométrique; une hypothèse qui participerait de l'une et de l'autre de ces progressions, semble devoir représenter à la fois les réfractions et* la diminution observée dans la chaleur des couches atmosphériques. La Place, *Mécanique Céleste*, tome IV. livre X. 261.

Table LXIX.

Decrements of Temperature observed at different Altitudes.

	Names of Places.	Altitude of the Columns of Air in Fathoms.	Temperature at the Lowest Stations.	Temperature at the Upper Stations.	Decrement for a depression of one degree, in Fathoms.
1	Gay Lussac's Aerostatic Ascent .. Paris	3816.12	87.4	14.9	95.14
2	Chimborazo .. South Sea	3214.64	77.5	29.1	119.75
3	Mont Blanc .. Geneva .. at noon	2391.70	82.9	26.8	76.55
4	at 2 o'clock	.....	81.7	29.1	82.02
5	Peak of Teneriffe .. Orotava .. (Cordier)	2039.01	76.8	47.1	123.58
6	Mont Blanc .. Chamouny .. at noon	2035.19	73.4	26.8	78.74
7	at 2 o'clock	.....	77.0	29.1	76.55
8	Etna .. Catania .. (Saussure)	1769.99	73.6	39.9	97.33
9	Mont Perdu .. Tarbes	1704.38	78.1	44.4	91.32
10	Giant's Neck .. Geneva	1673.21	76.8	40.1	82.02
11	Maladette .. Tarbes .. (Cordier)	1587.91	69.4	38.1	91.32
12	Pic du Midi .. Tarbes .. July 26, 1809	1428.79	81.5	52.9	89.68
13	Sept. 15	.....	67.3	47.5	130.14
14	Sept. 4, 1803	.....	72.5	46.6	98.97
15	Sept. 12	.....	74.3	50.7	108.81
16	Sept. 23	.....	65.8	46.6	133.42
17	Sept. 27	.....	66.4	39.2	94.60
18	Sept. 30	.....	58.6	39.7	136.15
19	Giant's Neck .. Chamouny	1303.57	70.9	40.1	76.01
20	Mont Perdu .. Barèges	1176.71	77.0	44.4	65.07
21	Pic d'Eyré .. Tarbes	1173.98	70.3	51.8	113.73
*22	Guanaxuoto .. South Sea	1139.53	77.5	70.3	284.88
23	Pic de Montaigu .. Tarbes	1122.58	58.1	37.6	98.42
*24	Pic de Bergons .. Tarbes	979.32	66.2	56.3	178.26
25	Pic du Midi .. Barèges .. Aug. 30, 1805	904.95	80.1	61.5	88.03
26	Sept. 15	.....	71.4	46.4	65.07
27	Aug. 15, 1809	.....	70.3	46.8	69.44
28	Sept. 23	.....	65.3	42.8	72.18
29	Oct. 19	.....	60.6	36.5	67.26
30	Sept. 11, 1810	.....	64.0	44.6	83.66
31	Sept. 22	.....	66.0	42.4	68.90
32	Sept. 28	.....	65.1	41.4	68.35
33	Puy de Dôme .. Clermont .. June 25, 1806	582.89	70.3	57.9	84.21
34	Oct. 11, 1807, at noon	.....	64.0	51.4	83.11
35	1 o'clock	.....	65.5	53.1	84.21
36	June 29, 1808	.....	76.6	59.4	60.69
37	Aug. 7	.....	91.2	74.1	61.24
*38	Mountain above Bagnères .. Tarbes	519.46	50.5	49.3	742.01
39	Bédat de Bagnères .. Tarbes	306.75	51.6	46.4	105.53
40	Pont du Berger .. Clermont	269.03	32.5	26.8	84.21
41	The Barracks .. Clermont	207.78	74.5	71.2	115.37
*42	Prudelle .. Clermont	156.93	82.9	77.0	47.57

Mean decrement resulting from the 42 Observations = 111.274 fathoms } for one degree of temperature.
Mean decrement by eliminating the Observations 22, 24, 38, and 42 = 90.058 fathoms }

ferences rom the able.

(317.) From this Table it appears, that the most rapid decrement of heat is at the rate of 61 fathoms, and the slowest 136 fathoms, to a centesimal degree. The mean rate deduced from all the observations is just 90 fathoms; and the extremes differ from the mean quantity, not by a small part of it, but by a half.

r. Ivory's marks on ano- alies.

And in reference to this subject, Mr. Ivory remarks,* that as we cannot doubt that the principle which distributes the difference of temperatures equally through the whole height of the column is nearly true, we must infer that the rate of decrease depends in a great measure upon circumstances peculiar to each particular case. In this respect, he says, causes seem to operate, which the observer is not only unable to appreciate, but even of the existence of which he has no indications. Very little confidence, therefore, can be placed in temperatures at different heights in the atmosphere, estimated by the rate of the decrease of heat; although the exactness of barometrical measurements is not by this means affected, the heat of the column of air being always determined by the temperatures actually observed at its extremities.

The instruments employed in determining the temperature may be one cause of the anomalies observed.

(318.) In endeavouring to account for the observed anomalies, Mr. Ivory remarks, that we may, perhaps, find in the nature of the instrument with which the heat is measured, some reason for the irregular deviations of the observed temperatures of the atmosphere from any theoretical law. The thermometer measures the temperatures of such bodies only as are in immediate contact with it. Local circumstances, impossible to be appreciated, may therefore so much affect a thermometer placed at the extremity of a column of air, as to make it indicate a temperature very different from that which would occur at a medium, and when all the causes which influence the propagation of heat through its entire length, have produced their due effect. In this manner the observed temperature may be made to diverge from that which is true, by the influence of a current of air in which the thermometer is placed; by the reflection of the Sun's rays from the surrounding

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* *Philosophical Magazine*, July 1821.

objects; by evaporation, and the radiation of heat depending upon the nature of the adjacent soil; and by other causes.

The deductions of Ramond for the decrement of heat generally adopted by Philosophers.

(319.) The rate of the decrease of heat deduced from the above-mentioned observations of Ramond, *viz.* 90 fathoms to a centesimal degree, or 100 yards to a degree of Fahrenheit, seems to be the quantity most generally adopted by Philosophers. By means of this relation, the temperatures which prevail at given altitudes in the atmosphere are sometimes determined with great precision, although in other cases the calculation differs much from the truth. Thus adopting the great height of 3817 fathoms, as determined by Gay Lussac in his magnificent aerostatic ascent, the difference of temperature, at the rate of 90 fathoms to a degree, will be found to be 42°.4, which is a near approximation to 40°.3, the quantity actually observed. On the other hand, if we apply the same rule to the extreme cases in the Table of Ramond, we shall obtain results quite unsatisfactory. The decrease of heat in the atmosphere, observes Mr. Ivory, as determined by the ascent of balloons, seems to follow a slower rate than in the case of altitudes on the Earth's surface. There can be no doubt that this manner of experimenting is free from many causes of irregularity to which terrestrial observations are subject. We may, therefore hope that by this means much light will be ultimately thrown on the gradation of heat in the atmosphere; but a sufficient number of accurate experiments are wanting to establish a conclusion in which confidence can be placed. In the case of Gay Lussac's ascent, we obtain a rate of nearly 95 fathoms to a centesimal degree, which is not very different from the mean found by terrestrial altitudes.

Observations respecting the increments of altitude and the depressions of the thermometer.

(320.) Could we remove from the atmosphere the many causes by which the natural and regular propagation of heat is continually disturbed, there is no doubt that the temperature would be found to decrease nearly in the same ratio as the altitude increases. This, however, must be understood with limitations. If we conceive the height of a column of air to be divided into portions corresponding to a constant difference of temperature, it is much more probable that these portions will form a progression increasing or decreasing slowly, than that they will constitute a series of increments perfectly uniform. Such, however, are the anomalies attending observations of the temperature of the atmosphere, that it is extremely difficult to determine, by experiment, whether the heat decreases in a less or greater ratio than the altitude augments. According to some Philosophers, the increment of altitude necessary for depressing the thermometer a single degree, is a quantity continually increasing the higher we ascend. But the contrary opinion, that the heat decreases more rapidly than the altitude increases, is most generally adopted, and, among others, by Humboldt and Ramond.

Theory of Leslie.

(321.) Professor Leslie has given a precise and mathematical theory of the variation of heat in the atmosphere, and exhibited it in a formula distinguished for its simplicity and beauty. If b denote the altitude of the mercury in a barometer, at the lower of two stations, and β the height at the upper; then if t denote the difference of temperature in centesimal degrees, we shall have, according to the Professor, the following relation

$$t = 25\left(\frac{b}{\beta} - \frac{\beta}{b}\right) \dots\dots (L).$$

His first fo mula.

This formula was first published in 1811, in the admirable Notes to that Author's Treatise on Geometry.

His secon formula.

(322.) In the Paper on *Climate*, contained in the *Supplement* to the *Encyclopædia Britannica*, the Professor, however, has exhibited it under another form, by substituting the ratio of the densities at the extremities of the elevation, for that of the barometrical pressures. This alteration in the elementary conditions of the formula, gives it the form of

$$25\left(\frac{1}{\theta} - \theta\right) \dots\dots (M),$$

where θ represents the density of the air.

Mr. Ivory' remarks o the second formula.

(323.) On this modification of the formula, Mr. Ivory properly observes, that the ratios of the densities and the barometrical pressures are not rigidly equivalent. For at the top of the column, the temperature is always less than at the bottom, and the density of a mass of air depends both on the pressure and the temperature. In all Mr. Leslie's investigations, however, in the Paper above quoted, he seems to have estimated the density by the pressure alone, making no distinction between the two formulæ.

(324.) Of the ingenuity and sagacity displayed by Professor Leslie in the experimental investigation of the formulæ too much cannot be said; and although it is Mr. Ivory's opinion, that their accuracy is limited to small elevations, it is wonderful, considering the circumstances attending the experiments, that their author has been able to deduce a result at all conformable to Nature.

Analytic investiga tion of Le lie's first mula.

(325.) To investigate the analytical conditions of the first of Leslie's formulæ, let b, β, denote, as before, the barometrical pressures at the inferior and superior limits of a column of air, whose altitude in fathoms is x. Then neglecting the correction dependent on temperature, as unnecessary in the present inquiry, we shall obtain by the usual rule*

$$10000 \log. \frac{b}{\beta} = x;$$

and as the logarithms in this formula are of the ordinary sort, and that they are to the hyperbolic logarithms in the ratio of 4343 to 10000, we shall, therefore, have

$$10000 \log. \frac{b}{\beta} = 4343\, h\,.\log. \frac{b}{\beta};$$

and from which we may derive

$$h\,.\log. \frac{b}{\beta} = \frac{x}{4343}.$$

To simplify this last equation, let $a = \frac{1}{4343}$; and adopting l as the base of the hyperbolic logarithms, we shall obtain

$$h\,.\log. \frac{b}{\beta} = h\,.\log. l^{ax};$$

or passing from logarithms to numbers,

$$\frac{b}{\beta} = l^{ax}.$$

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* Playfair, *Outlines of Natural Philosophy*, vol. i. p. 247. sec. 341.

Taking the reciprocal of this last equation, we have

$$\frac{\beta}{b} = l^{-ax},$$

and therefore

$$\frac{b}{\beta} - \frac{\beta}{b} = l^{ax} - l^{-ax};$$

or by expanding the latter member into a series, we have

$$\frac{b}{\beta} - \frac{\beta}{b} = 2\,a\,x \left\{1 + \frac{a^2\,x^2}{6} + \&c.\right\}.$$

If now we adopt for the decrement of temperature, 90 fathoms for every centesimal degree, which is the quantity employed by Leslie, we shall have

$$x = 90\,t;$$

and therefore the preceding equation will become

$$\frac{b}{\beta} - \frac{\beta}{b} = 180\,a\,t \left\{1 + \frac{1}{6}(90\,a\,t)^2 + \&c.\right\}.$$

But

$$180\,a = \frac{180}{4343} = \frac{1}{25} \text{ nearly};$$

and

$$90\,a = .0207 = \frac{2}{100} \text{ nearly}.$$

Hence

$$\begin{aligned}\frac{b}{\beta} - \frac{\beta}{b} &= \frac{1}{25}\,t \left\{1 + \frac{1}{6}\left(\frac{2\,t}{100}\right)^2 + \&c.\right\}\\ &= \frac{1}{25}\,t \left\{1 + \frac{2}{3}\left(\frac{t}{100}\right)^2 + \&c.\right\},\end{aligned}$$

or

$$25\left(\frac{b}{\beta} - \frac{\beta}{b}\right) = t \left\{1 + \frac{2}{3}\left(\frac{t}{100}\right)^2 + \&c.\right\}.$$

But, for small differences of temperature, the series forming the right-hand member of the equation may be regarded as equivalent to unity; and therefore we shall obtain

$$t = 25\left(\frac{b}{\beta} - \frac{\beta}{b}\right),$$

which is the first of Professor Leslie's formulæ.

Further remarks of Mr. Ivory on Mr. Leslie's theory.

(326.) The truth of Mr. Leslie's theory is therefore confirmed, at least for moderate elevations. Mr. Ivory, who was at first disposed to question its accuracy in the case of its application to Gay Lussac's ascent, making its deviation a tenth of the whole,[*] in a later publication[†] seems to regard it with a more favourable eye. The mean elevation, says he, for one degree of depression of the centigrade thermometer, is very nearly 90 English fathoms; and in the great height ascended by Gay Lussac, rather more than four miles and a quarter, the same quantity comes out 95 fathoms. To this great extent the law of a uniform decrease of temperature holds good, without much deviation from the truth. It therefore seems to be the assumption most likely to guide us aright in approximating to the true constitution of the atmosphere.

(327.) Of the second formula furnished by Mr. Leslie, it may be remarked, that nothing can exceed its simplicity and beauty. It may be enunciated in ordinary language as follows: Multiply the constant coefficient 25 into the difference between the density of the air and its reciprocal, and the result will represent the measure of heat due to the change of condition. This result may be either *plus* or *minus*: it may express the heat emitted in the condensation of air, or the heat absorbed during its opposite rarefaction.

Practical example of its use.

(328.) To illustrate, by a practical example, the uses of this formula, let it be required to estimate the heat liberated from air, when its density is tripled. In this case the formula will assume the numerical form of

$$25\left(3 - \frac{1}{3}\right) = 66^\circ\,\frac{2}{3},$$

which is the measure of the heat liberated; and the same quantity is withdrawn, either when the air recovers its former density, or when air of the ordinary state expands into triple its volume. A computation of equal simplicity will enable us to estimate the copious liberation of heat extricated by great and sudden condensations. The pneumatic matches invented by Mollet, which produce their effect by the momentary action of a small syringe, afford a beautiful experimental proof of the theory.

(329.) Professor Leslie was led to the creation of the preceding formulæ, by many delicate and refined experimental investigations connected with the increased capacity of rarefied air. Mr. Atkinson, in pursuing the same inquiry, has adopted another course, and endeavoured to deduce the laws which connect the altitude and temperature together, by an appeal to actual observation. His investigations on this important subject are contained in his *Memoir on the Astronomical Refractions* before quoted.

Views of Mr. Atkinson on the decrement of temperature.

(330.) Mr. Atkinson adopts as a basis for his inquiries, the results of a number of barometrical and thermometrical observations collected by General Roy, and others, with a view of obtaining a more correct rule for determining the altitudes of mountains. These Tables may be seen in the *Transactions of the Astronomical Society*, vol. ii. p. 151, &c., and their results are contained in the next Table. It will be remarked, that all the observations are confined to the North temperate zone.

TABLE LXX.

Names of Places.	Number of Observations.	Sums of the Differences of Temperatures.	Sums of the Altitudes.
Near Taybridge	9	52°.75	15143.0
Near Lanark	14	56.00	13224.5
Near Edinburgh	17	32.25	12345.4
Near Linhouse............	8	33.00	7040.8
Near Caernarvon	12	153.25	39108.0
Cape of Good Hope	2	32.00	6857.0
Certain heights determined by the barometer	15	109.50	26041.2
Observations of M. de Luc ..	31	240.00	64764.6
Skiddaw	20	112.00	28710.0
Totals	128	820.75	213234.5

Deductions from Table.

(331.) Of the third column in this last Table, named Differences of Temperature, it may be remarked, that it contains the sums of the successive differences of

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[*] *Philosophical Magazine*, vol. lviii. p. 30.

[†] *Philosophical Transactions*, 1823, p. 437.

temperature observed at the highest and lowest stations of observation contained in the Tables referred to in the *Astronomical Transactions;* and the column devoted to the Altitudes, the aggregate amount of the different altitudes between the same points of observation.

By dividing the aggregate amount of these altitudes by the number of observations, we shall obtain the mean altitude of all the observations

$$=\frac{213234.5}{128}=1665.9 \text{ feet.}$$

In like manner, the sum of the differences of temperature divided by the same number of observations, will give $\frac{820.75}{128}=6^\circ.412$ of Fahrenheit, for the *mean depression* of the thermometer due to the *mean height* of the observations.

(332.) By referring also to Table XXXV., we shall find the

	Feet.
Sum of the altitudes in the first column of heights	= 18480
.... second............	= 13816
Total..........	32296

And dividing this total by 22, the number of observations contained in the Table, we shall obtain $\frac{32296}{22}=1468$ feet, the average altitude of the whole; and hence the depression of the thermometer due to the same elevation will, by the same Table, be according to

$$\text{Brewster's first formula } \frac{83^\circ.87+47^\circ.24}{22}=5^\circ.960,$$

$$\text{Brewster's second formula } \frac{72^\circ.09+49^\circ.87}{22}=5^\circ.544,$$

$$\text{Mayer's formula } \frac{80^\circ.22+44^\circ.69}{22}=5^\circ.678,$$

$$\text{and by Daubuisson's formula } \frac{78^\circ.72+43^\circ.30}{22}=5^\circ.546.$$

The mean of these gives 5°.682 for the mean depression of the thermometer at the height of 1468 feet, as deduced from the twenty-nine places recorded in Tables XXXIII., XXXIV., and XXXV.

(333.) From the preceding and other analogous considerations, Mr. Atkinson deduces the five following results:

TABLE LXXI.

Number of the Results.	Different Altitudes in Feet.	Depression of the Mean Temperature.
1	1468	5°.682
2	1666	6.412
3	3624	13.683
4	6597	23.850
5	10386	33.480

And from this last Table may be derived

TABLE LXXII.

Number of the Results.	Average Height due to each Degree of Depression, in Feet.
1	258.360
2	259.825
3	264.854
4	276.604
5	310.215

The gradation of heat is not that of an equable decrease when the altitude uniformly increases.

(334.) By a reference to this last Table it appears, that the law which represents the gradation of heat in the atmosphere, is far from being that of an equable decrease, when the altitude increases uniformly. At the same time it appears, that when the *decrements* of temperature are uniform, the *increments* of altitude constitute an arithmetical series.

(335.) To determine, however, whether this law is in conformity to Nature, let the uniform decrement of temperature be represented by a single degree of Fahrenheit's scale, and the corresponding increments of altitude by the series

$$x,\ x+y,\ x+2y,\ x+3y,\ \&c.$$

wherein the first term x represents the height due to the first degree of diminution of temperature from the level of the sea, and y the common difference appertaining to the whole progression. Let also n and n' denote the number of degrees which the temperature is depressed, at the elevations h and h'. We shall then have

$$x+(x+y)+(x+2y)\ldots.(x+(n-1)y)=h,$$

and

$$x+(x+y)+(x+2y)\ldots.(x+(n'-1)y)=h',$$

or

$$nx+\frac{n^2-n}{2}y=h,$$

and

$$n'x+\frac{(n')^2-n'}{2}y=h'.$$

From these last equations we obtain

$$x=\frac{h}{n}-\frac{n-1}{2}y\ldots..(N),$$

and

$$y=\frac{2\left(\frac{h'}{n'}-\frac{h}{n}\right)}{n'-n}\ldots.(O).$$

Applicati of the for mulæ to mean results befc obtained.

(336.) Applying these formulæ to the five mean results before obtained, and comparing the

			Feet.
5th with the 1st, we obtain	$y=3.73$	and	$x=249.63$
5th....... 2d..........	$y=3.72$	....	$x=249.76$
5th....... 3d..........	$y=4.58$	....	$x=235.81$
4th....... 1st..........	$y=2.01$	....	$x=253.66$
4th....... 2d..........	$y=1.92$	....	$x=254.63$
4th....... 3d..........	$y=2.31$	....	$x=250.21$

which makes the mean value of......... $y=3.045$
and the mean value of................. $x=248.95$

(337.) All the depressions agree, it may be remarked, in giving a positive value to y, although it varies by a comparison of different results. It seems not improbable, however, that this variation arises from the un-

Mr. Atkinson's inferences.

avoidable errors of observation: for if the 4th depression be diminished only 0°.6, and the 5th increased by 0°.75, the values of y, found as above, will be found to approach to uniformity. It may hence be inferred, says Mr. Atkinson, that the law which has been assumed, is either the true law, or nearly so; though it is evident that we are not yet in possession of observations sufficiently numerous and varied, to enable us to determine whether the law has an actual existence or not. The observations at present known are, however, sufficient to bring the uncertainty that may exist respecting the values of x and y, into comparatively narrow limits.

(338.) If we adopt for the mean value of y just deduced, the numeral 3, we shall find, by employing the depressions corresponding to the height of 1468 feet, the value of x equivalent to an altitude of 251.3 feet. Hence the following formula is obtained for the height due to any given depression of the thermometer n:

$$\left\{251.3 + \frac{3}{2}(n-1)\right\} n = h \ldots . (\mathrm{P}).^{*}$$

(339.) By applying this formula to the depressions and altitudes recorded in Table LXX., we shall obtain the results recorded in

TABLE LXXIII.

When the depression of the thermometer is	The height according to observation is	The height by the formula is	Difference in feet.	Difference in degrees of Fahrenheit.
5°.682	1468	1467.8	− 0.2	−0.°00
6.412	1666	1663.4	− 2.6	−0.01
13.683	3624	3698.8	+ 74.8	+0.26
23.850	6597	6811.0	+214.0	+0.67
33.480 or 34.680	10386	10044.7 or 10467.1	−341.3 or + 81.1	−0.98 or +0.23

Application of the same system of gradation to the tropical atmosphere.

(340.) Let us next endeavour to inquire if the same system of gradation holds good in the temperature of the tropical atmosphere.

Mr. Atkinson, in entering on this subject, endeavours by the application of certain corrections, to deduce the temperature of the free atmosphere, from the temperatures of the elevated places that have been visited in the tropics. The air which rests on the plains of the Andes, says Humboldt, although it becomes mixed with the great mass of the free atmosphere, presents, nevertheless, a surprising stability of temperature. However enormous be the mass of the Cordilleras, it acts but feebly on the strata of air which are unceasingly renewed. From these, and other considerations, Mr. Atkinson has deduced the following

Scale of Corrections.

Scale of corrections deduced from the observations of Humboldt.

When the plain is of small extent we may subtract....................................	2°.70	from the observed mean temperature.
For a small valley, or a plain of considerable extent	3.42	Ditto.
For large extended plains, or for warm valleys	4.14	Ditto.
For large sheltered valleys at great heights above the sea	4.50	Ditto.

And hence he remarks, that if the correction due to the *situation* of any place in South America, near the Equator, be taken from its observed mean temperature, the remainder will be a close approximation to the mean temperature of the free atmosphere, at the same elevation. In this manner the sixth column of the following Table was computed; and the depression of the thermometer due to the elevation of each place, is evidently found, by subtracting the temperature of the free atmosphere from the mean temperature at the level of the sea in the given latitude. The altitudes, it will be perceived, are comprised between 2000 and 5000 feet.

TABLE LXXIV.

Names of Places.	Height in feet.	Latitude.	Observed Mean Temperature of Places.	Correction of Temperature on account of Localities.	Mean Temperature of free Atmosphere at same Height.	Correction for Latitude.	Mean Temperature at Level of the Sea in that Latitude.	Depression of the Thermometer due to the Height.
Caraccas	2906	10°31′ N.	69°.44	0°.00	69°.44	2°.44	82°.06	12°.62
Carthago	3149	4 46	74.84	4.14	70.70	0.50	84.00	13.30
La Plata	3437	2 24	74.66	4.14	70.52	0.13	84.37	13.85
Guaduas	3772	....	67.46	....	67.46	....	84.50	17.04
La Meya	4225	....	72.50	....	72.50	....	.....	12.00
Medellin	4868	....	68.90	....	68.90	....	.....	15.69
	5)19441							5)71.79
	Mean height = 3888						Mean depression of the thermometer =	14.36

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* A very neat approximative value for n may be thus obtained.

Since $$\left\{251.3 + \frac{3}{2}(n-1)\right\} n = h,$$

we shall obtain $$n = \frac{h}{251.3 + \frac{3}{2}(n-1)}.$$

But $$\frac{3}{2}(n-1) \text{ being nearly } \frac{3}{2} \times \frac{h}{300} = \frac{h}{200},$$

we shall have $$n = \frac{h}{251 + \frac{h}{200}}.$$

This will enable the reader fully to understand the formula (K), p. 49, and which we before employed in p. 36.

(341.) By a similar method of proceeding, the succeeding Tables have been computed. The altitudes in Table LXXV. are comprised between five thousand and eight thousand feet.

TABLE LXXV.

Names of Places.	Height in feet.	Latitude.	Observed Mean Temperature of Place.	Correction of Temperature on account of Localities.	Mean Temperature of free Atmosphere at same Height.	Correction for Latitude.	Mean Temperature at Level of the Sea in that Latitude.	Depression of the Thermometer due to the Height.
Estrella	5645	....	65°.84	....	65°.84	....	84°.50	18°.66
Popayan	5815	2° 29′ N.	65.66	3°.42	62.24	0°.14	84.36	22.12
Loxa	6855	3 59 S.	64.40	3.42	60.98	0.35	84.15	23.17
Almaguer	7413	1 56 N.	62.60	2.70	59.90	0.08	84.42	24.52
Alausi	7970	2 12 S.	59.00	2.70	56.30	0.11	84.39	28.09
	5)33698							5)116.56
Mean height =	6740						Mean depression of the thermometer =	23.31

The altitudes in the next Table are comprised between eight thousand and ten thousand feet.

TABLE LXXVI.

Names of Places.	Height in feet.	Latitude.	Observed Mean Temperature of Place.	Correction of Temperature on account of Localities.	Mean Temperature of free Atmosphere at same Height.	Correction for Latitude.	Mean Temperature at Level of the Sea in that Latitude.	Depression of the Thermometer due to the Height.
Pamplona	8016	7° 01′ N.	61°.16	4°.50	56°.66	1°.09	83°.41	26°.75
Pasto	8308	1 15	58.28	4.14	54.14	0.03	84.47	30.33
Santa Rosa	8459	......	57.74	....	54.74	....	84.50	26.76
Cueuça	8633	2 55 S.	60.08	4.14	55.94	0.19	84.31	28.37
Santa Fé de Bogota	8721	5 24 N.	57.74	4.14	53.60	0.65	83.85	30.25
Hambato	8849	1 14 S.	60.44	4.50	55.94	0.03	84.47	28.53
Caxamarca	9381	6 54	60.80	9.10	51.70	1.05	83.45	31.75
Llactacunga	9473	0 55	59.00	4.50	54.50	0.02	84.48	29.98
Riobamba Nuevo	9482	1 42	61.16	9.10	52.06	0.06	84.44	32.38
Tunja	9522	5 05 N.	56.66	4.14	52.52	0.57	83.93	31.41
Quito	9538	0 13 S.	57.92	4.50	53.42	0.00	84.50	31.08
Malbasa	9971	2 28 N.	54.50	3.42	51.08	0.16	84.34	33.26
	12)108353							12)360.85
Mean height =	9029						Mean depression of the thermometer =	30.07

(342.) The altitudes also in the succeeding Table are found between ten thousand and twelve thousand feet.

TABLE LXXVII.

Names of Places.	Height in feet.	Latitude.	Observed Mean Temperature of Place.	Correction of Temperature on account of Localities.	Mean Temperature of free Atmosphere at same Height.	Correction for Latitude.	Mean Temperature at Level of the Sea in that Latitude.	Depression of the Thermometer due to the Height.
Plateau de los Pastos	10099	......	54°.50	2°.70	51°.80	....	84°.50	32°.70
Les Paramos	11480	4° 36′ N.	47.30	....	47.30	0°.47	84.03	36.73
	2)21579							2)69.43
Mean height =	10790						Mean depression of the thermometer =	34.715

(343.) In addition to these, Mr. Atkinson adds, that at the altitude of 15748 feet, the inferior limit of perpetual snow, a mean depression of temperature was found equivalent to 49°.62; and by an observation of Humboldt, made at One P. M., in June, a depression of 57°.38 was found on Chimborazo, at the elevation of 19,286 feet.

(344.) The different results thus obtained are inserted in the following Table:

Table of General Results.

Table LXXVIII.

Number of the Results.	Altitudes in Feet.	Corresponding mean depressions of the Thermometer in degrees of Fahrenheit.
1	3724	14°.070
2	6740	23.310
3	9029	30.070
4	10790	34.715
5	15748	49.620
6	19286	57.380

Inferences from it.

(345.) From this Table it may be inferred, that the gradation of heat in the portion of the atmosphere surrounding the torrid zone, actually coincides, or nearly so, with what has been shown to exist in the atmosphere of Europe. And, in order to investigate its condition more accurately, we may, as before, demonstrate, that if the *decrements* of temperature be regarded as uniform, the *increments* of elevation may be very nearly represented by an arithmetical series, whose first term is x, and common difference y.

Application of the formulæ (N) and (O) to the results of the last Table.

Applying therefore the formulæ (N) and (O) deduced from this supposition, to the results contained in the preceding Table, we shall obtain by comparing

Feet.

the 6th with the 1st, $y = 3.30$

6th........2d, $y = 2.76$

6th........3d, $y = 2.62$

5th........1st, $y = 2.96$

5th........2d, $y = 2.14$

4th........1st, $y = 4.47$

which makes the mean value of $y = 3.04$.

Taking, therefore, $y = 3$,

Feet.

the 1st result gives $x = 245.08$

2d............$x = 255.64$

3d............$x = 256.66$

4th...........$x = 260.23$

5th...........$x = 244.37$

6th...........$x = 251.53$

which makes the mean value of $x = 252.25$.

And therefore in a general way we may regard the values of x and y, as 252 and 3 respectively.

Further attempt to deduce the elements x and y.

(346.) But to obtain these values as accurately as the observations will admit, let the true value of $x = 252 + x'$, and that of $y = 3 + y'$. Substituting these in formula (N), and transposing, we obtain

$$252 + x' + \frac{n-1}{2}(3 + y') - \frac{h}{n} = 0,$$

if both the observations and formula be correct. If, however, one or both be incorrect in a small degree, we shall then have

$$252 + x' + \frac{n-1}{2}(3 + y') - \frac{h}{n} = \mathrm{E},$$

Formation of the necessary equations of condition.

in which E represents some unknown error.

(347.) Applying this last formula to each of the six mean results, we shall obtain the following equations of condition, for determining the values of x' and y':

$$x' + 6.535\,y' + 6.92 = \mathrm{E}_1$$
$$x' + 11.155\,y' - 3.68 = \mathrm{E}_2$$
$$x' + 14.535\,y' - 4.66 = \mathrm{E}_3$$
$$x' + 16.860\,y' - 8.25 = \mathrm{E}_4$$
$$x' + 24.310\,y' + 7.64 = \mathrm{E}_5$$
$$x' + 28.190\,y' - 6.46 = \mathrm{E}_6.$$

Application of minimum squares to them.

And hence by the method of minimum squares we find

$$x' = +1.428,$$

and

$$y' = -.06889.$$

Hence we shall have

$$x = 253.4 \text{ feet},$$

and

$$y = 2.9311 \text{ feet}.$$

Values of the elements when particular quantities are omitted.

If the last be omitted, we shall have $x = 253.478$ and $y = 2.927$

..... 5th....................$x = 251.060$ and $y = 3.180$

..... 4th....................$x = 251.796$ and $y = 2.933$

..... 5th and 6th.............$x = 237.330$ and $y = 4.390$

..... 3d and 4th..............$x = 249.380$ and $y = 2.988$.

And since the values of x and y, already adopted for Europe, were 251.3 and 3, it is evident that, so far as the observations in Europe and America can be depended on, the law representing the gradation of heat in the atmosphere, is the same both for the temperate and torrid zones.

Inference respecting the frigid zones.

Reasoning also on general principles we may infer, that it will either be the same, or nearly so in the frigid zones.* The formula (P) therefore before deduced for the temperate zone, may be likewise applied to the torrid zone, and to all the varieties of altitude contained in Table L. The following Table has been added to indicate the degree of confidence that may be placed in the formula.

Table LXXIX.

Europe.				America.			
Height in Feet.	Observed Depression of Temperature.	Calculated Depression.	Error of Formula.	Height in Feet.	Observed Depression of Temperature.	Calculated Depression.	Error of Formula.
1468	5°.682	5°.682	0°.00	3724	14°.070	13°.77	+0°.300
1666	6.412	6.422	−0.01	6740	23.310	23.63	−0.320
3624	13.683	13.423	+0.26	9029	30.070	30.55	−0.480
6597	23.850	23.180	+0.67	10799	34.715	35.62	−0.905
10386	33.480	34.450	−0.97	15744	49.620	48.75	+0.870
				19286	57.380	57.41	−0.030

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* We are only acquainted with a single experimental observation made with a view of discovering the decrement of temperature in high latitudes. This experiment was performed by the Rev. George Fisher, and the intrepid navigator Captain Sir Edward Parry, at the Island of Igloolik, in lat. 69° 21′ N., and long. 81° 42′ W.

A paper kite was hoisted, to which was attached an excellent register thermometer, in a horizontal position. Its height above the level of the frozen sea, upon which the experiment was made, was determined by two observers in the same vertical plane, taking its altitude at the same time above the distant horizon; and thence its height was computed. The greatest height observed was 379 feet, at which it was nearly stationary for a quarter of an hour, although it had probably been more than 400 feet above the sea. The experiment was made under very favourable circumstances, the kite being sent up and caught in coming down, without the slightest agitation. "*The indices,*" says Mr. Fisher, "*had not altered their position in the slightest degree*, and they would have indicated any variation of temperature, had it

The differences between the observed and calculated temperatures are quite within the limits of observation; and the formula employed may therefore be regarded as exhibiting, with tolerable accuracy, the relation between the temperature and the height, in the mean state of the atmosphere, up to the greatest altitude at which observations have yet been made.

Humboldt's opinions respecting the decrease of heat in the atmosphere of the torrid zone.

(348.) On the decrease of temperature in the atmosphere of the torrid zone, Humboldt is of opinion, that in its mean state, the heat does not decrease uniformly in an arithmetical progression. This he infers from the observations recorded in the following Table.

TABLE LXXX.

Heights in		Equatorial Zone, from 0° to 10°.		Temperate Zone, from 45° to 47°.	
Metres.	Feet.	Mean Temperature.	Difference.	Mean Temperature.	Difference.
0	0	81°.50			
974	3195	71.24	10°.26	53°.60	
1949	6393	65.12	6.12	41.00	12°.60
2923	9587	57.74	7.38	31.64	9.36
3900	12792	44.60	13.14	23.36	8.28
4872	15965	34.70	9.90		

Alterations in the decrements of temperature at different altitudes.

In the Cordilleras, says Humboldt, (and the fact is extremely curious,) we observe the decrease getting less and less between 1000 and 3000 metres, particularly between 1000 and 2500 metres of elevation, and then increasing anew from 3000 to 4000 metres. The strata, says that distinguished traveller, where the decrease attains its maximum and minimum, are in the ratio of 1 to 2. From the height of the Caraccas to that of Popayan and Loxa, 1000 metres produce a difference of 6°.3. From Quito to the height of Paramos, the same 1000 metres change the mean temperature more than 12°.6. Do these phenomena, inquires Humboldt, depend only on the configuration of the Andes, or are they the effect of the accumulation of clouds in the aerial ocean? In considering that the Andes form an enormous mass, from which rise lofty peaks or domes insulated and covered with snow, we may conceive how, from the point where the mass of the chain diminishes so rapidly, the heat decreases also with rapidity. It is not easy, however, to explain by an analogous cause, why the progressive cooling diminishes between 1000 and 2000 metres. This eminent man supposes the slowness with which the heat decreases in the stratum of air between 1000 and 2000 metres to be the triple effect of the extinction of light, or the absorption of the rays in the clouds, of the formation of rain, and the obstacle which the clouds present to the free passage of radiant heat. The bed of air here referred to by Humboldt, is the region in which are suspended the large clouds which the inhabitants of the plains see above their heads. The decrease of temperature, which is very rapid from the plains to the region of the clouds, becomes less rapid in that region; and if this change is less sensible in the temperate zone, it arises from the effects of radiation being less sensible at the same height, than above the burning plains of the equinoctial zone.

Attempt to explain the cause.

Humboldt' results respecting th decrement of temperature.

(349.) The following Table contains the results of Humboldt's researches on this interesting subject. The measures recorded in the third column indicate the mean result, or the measure of the distribution of heat in the whole column of air.

TABLE LXXXI.

Part of the Globe.	Extreme Altitudes in Metres.	Altitudes corresponding to the Temperatures of the next Columns in Metres.	Temperatures.	
			Cent.	Fahr.
Equinoctial Zone..	0—4900	187	1°	1°.8
Temperate Zone ..	0—2900	174	1°	1°.8

(350.) By observations made during solitary excursions to the tops of some lofty mountains, Humboldt has deduced the results contained in the next Table.*

TABLE LXXXII.

Part of the Globe.	Altitudes corresponding to the Temperatures of the next Columns in Metres.	Temperatures.	
		Cent.	Fahr.
Equinoctial Zone....	190	1°	1°.8
Temperate Zone....	160—172	1°	1.8

(351.) The coincidence in the results of the two last Tables is certainly remarkable; and when we consider that we have compared stationary with insulated observations, and hence confounded the mean state of the atmosphere in the course of a whole year, with the decrease which corresponds to a particular season, or some accidental hour of the day, the agreement is still more singular.

Dr. Youn attempt t deduce tl gradation temperat from the mean refractions.

(352.) Dr. Young, in the VIIIth number of the *Astronomical and Nautical Collections*, published in the *Journal of the Royal Institution*, has also endeavoured to deduce the gradations of temperature in the atmosphere, from the mean refraction; and the result of his inquiry is to give 208 feet for the altitude corresponding to the depression of a single degree of Fahrenheit's thermometer.

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existed, to less than a quarter of a degree, Fahrenheit." The temperature at the time was — 24° Fahrenheit.

Dr. Young, in alluding to this interesting experiment, remarks, that the law of decrease of temperature must be supposed to be very different in the Arctic regions from that which prevails in more moderate latitudes. The inference, however, is by far too sweeping, resting as it does on a single experiment. We may hope, however, that time will make known more perfectly many of the Physical conditions of the Polar regions.

* Humboldt obtained a series of partial results from the back of the Andes, of which the following is an abstract.

Heights in Metres.	Cent.		Fahr.		Metres.
0—1000	1°	or	1°.8	for	170
1000—2000	1	..	1.8	..	294
2000—3000	1	..	1.8	..	232
3000—4000	1	..	1.8	..	131
4000—5000	1	..	1.8	..	180.

In these numbers, we recognise the influence of the region of clouds upon the decrease of heat.

Remarks respecting the data on which the general investigation rest.

(353.) The experimental data on which all our conclusions on this interesting subject rest, are not entirely unexceptionable. The circumstances are so varied under which many of the experiments have been performed, and such is the changing character of the atmosphere, even in the short intervals of observation, that much remains to be done to perfect the inquiry. Not only do the results of observation vary for the same place, under different conditions of the atmosphere, but many anomalies arise from the various circumstances attending the relative situations of the heights at which the observations are made. If the lowest point, for example, be on a level plain, and the highest exist in the free air, the decrease must be very different from what it would be, if the lowest point were at the bottom, and the highest on the summit of a mountain; or if the observations were made at the lowest and highest points of a great city, at the sea-side, or on the summit of a hill in the interior. Nor is it always that the highest point is of the lowest temperature during the day, the atmosphere exhibiting sometimes, in this respect, a remarkable analogy to what takes place on nights most favourable to the production of dew.*

Anomalous observations made by Roy.

(354.) Among the observations made by General Roy on the temperature of the upper regions of the air, it may not be unimportant to notice the following, on account of their exhibiting anomalous results.

Table LXXXIII.

Stations.	Time of Observation.	Difference of Temperature.
Green Wharf at Woolwich Warren, and the upper story of Shooter's Hill Inn. Difference of height 444 feet.	1774, April 27, 4 P.M. Mean of 4 observations. April 27, 6h 30m P.M. Mean of 2 observations. April 28, 5 A.M. Mean of 5 observations.	6° *warmer* at the higher station. 0½° *warmer*, do. 1¾° *colder*, do.
Station at Weem, and top of Weem Craig, 700½ feet.	1774, July 16, 11h 30m A.M. Bright sunshine.	5½° *colder*, do.
Station at Weem, and top of Bolfracks Cairn, 1176½ feet.	July 16, 6h 30m P.M. Calm and cloudy.	3½° *colder*, do.
Station at Weem, and top of Dull Craig, 1244½ feet.	July 18, 7h 20m A.M.	2° *colder*, do.
Level of the Clyde at Lanark Bridge, and the Station at the Garden, 362½ feet.	Sept. 7, 7h 47m A.M. —— 9 0 ——	1° *colder*, do. 6° *colder*, do.
Level of the Clyde, and Stonebyre Hill, 654 feet.	Sept. 7, 8h 15m A.M.	1° *colder*, do.
Base of Hawk-hill Observatory, and bottom of the small rock on Arthur's Seat, 684 feet.	1776, Jan. 31, 10h 45m A.M. July 25, 2 20 P.M.	6° *warmer*, do. 2¾° *colder*, do.
Hawk-hill Garden-door, and bottom of the rock on Arthur's Seat, 730.8 feet.	1775, Dec. 27, 11h 30m A.M. —— 8 40 —— 1776, Feb. 1, 9 30 ——	*No difference.* 3¼° *colder* at the higher station. 2° *warmer*, do.

With greater altitudes the fluctuations diminish.

(355.) As the altitude increases, the fluctuations diminish, but they still exist to a great degree, as will appear from the following Table, containing observations made at Caernarvon Quay, and the top of Snowdon.

Table LXXXIV.

Altitude.	Day of Observation.	Hour of Observation.	Difference of Temperature of two Stations.
3555 feet.	1775, Aug. 7.	6h 7m A.M.	11¼° Colder at the higher station.
	....	9 7 ——	12¾° ditto
	....	0 7 P.M.	7¾° ditto.
	....	2 7 ——	11° ditto.
	14.	8 7 A.M.	12¼° ditto.
	....	0 7 P.M.	16° ditto.

Different results obtained for the *Pic du Midi*.

(356.) In like manner we shall find with reference to the observations made on the *Pic du Midi*, and given in Table LXIX., that the following differences of temperature were found on the different days recorded.

Table LXXXV.

Altitude.	Day of Observation.	Difference of Temperature at the two Stations, the upper being the coldest.
1428.79 feet.	July 26, 1809.	60°.6
	Sept. 15 ——	51.8
	Sept. 4, 1803.	57.9
	Sept. 12 ——	55.6
	Sept. 23 ——	51.3
	Sept. 27 ——	59.2
	Sept. 30 ——	50.9

For Mont Blanc.

(357.) So also for two observations made with reference to Mont Blanc, one at noon, and the other at two P.M., the difference of the temperatures for the former period was 88°.2, and for the latter 84°.6. These variations necessarily produced corresponding changes in the values of the decrements of altitude, that for the first set of observations being 76.55 fathoms, and for the second 82.02 fathoms. But with respect to the Puy de Dome, contained also in Table LXIX., we shall find that for two observations made respectively at noon, and one P.M., the difference of temperature for the former was 44°.6, and for the latter 44°.4. The decrements of temperature hence nearly correspond. Similar observations made at the same place on the 29th of June, 1808, and the 7th of August of the same year, produced in the former case, a difference amounting to 49°.3, and in the latter to 49°.1. These equal differences of temperature produced nearly equal decrements of altitude, but when compared with the former decrements of the same kind afford a difference of nearly 23 fathoms for a single degree of Fahrenheit.

Equality in the observations for the Puy de Dome.

Brisbane's observations for different hours of the day.

(358.) Sir Thomas Brisbane, to whom Astronomy is in particular is under such lasting obligations, pursued the subject of the variations of temperature at a constant difference of altitude for different hours of the day,

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* "On every clear and still night, the air nearest the earth is colder than that which is more distant from it, to the height at least of 220 feet, this being the greatest to which Mr. Six's experiments relate." Wells, *On Dew*, p. 95. 2d edit.

at Port Macquarie, Van Dieman's Land. His results are contained in the following Table, and were derived from a difference of altitude corresponding to 52 feet.

TABLE LXXXVI.

Period of the Day when the Observations were made.	Difference of Temperature in Fahrenheit's degrees.
Mean difference of temperature at Sunrise.	−6°.00
at 9 A. M.	−9.01
at Noon.	−7.55
at 3 P. M.	−5.50
at Sunset.	−3.50
Mean..	−6°.31
Maximum difference at Sunrise.	−13°.0
at 9 A. M.	−25.0
at Noon.	−18.0
at 3 P. M.	−11.0
at Sunset.	− 9.5
Minimum difference at Sunrise.	0.0
at 9 A. M.	+ 1.5
at Noon.	+ 0.5
at 3 P. M.	+ 0.0
at Sunset.	+ 3.0

These anomalies in the temperature must be attended with corresponding differences in the decrements of altitude.

Observations of Saussure on the effects of the seasons on the decrements of altitude.

(359.) Saussure, in his Meteorological inquiries, deduced the decrements both for summer and winter, assigning to the former season a decrement of 292 feet for a degree of Fahrenheit's thermometer, and to the latter 419 feet. For the whole year he assigned 356 feet.

(360.) The preceding remarks show, that to proceed successfully in this inquiry, a great number of contemporaneous observations should be made, at different seasons of the year and at different times of the day, in order to deduce from them the mean condition of the atmosphere.

Dr. Wilson's suggestion of determining the decrements of temperature by balloons.

(361.) One of the best methods that could be adopted for determining the decrements in question, would be the carrying into execution, on an extended scale, a suggestion originally made by the late Dr. Wilson, Professor of Practical Astronomy in Glasgow. An account of Dr. Wilson's method may be seen in the *Transactions of the Royal Society of Edinburgh*, vol. x. p. 2. and is briefly as follows.

Several paper kites of a large size were raised one above another, upon the same line, with (register) thermometers attached to them. Mr. Wilson began with raising the smallest kite, which, being exactly balanced, soon mounted steadily to its utmost limit, carrying up a very slender line, but of a strength sufficient to command it. In the mean time, the second kite was supported by two assistants, in a sloping direction, with its breast to the wind, and with its tail laid out evenly upon the ground behind, whilst a third person, holding part of its line tight in his hand, stood at a good distance directly in front. Things being thus ordered, the extremity of the line belonging to the kite already in the air was hooked to a loop at the back of the second, which being now let go, mounted very superbly, and in a little time also took up as much line as could be supported with advantage; thereby allowing its companion to soar to an elevation proportionally higher.

Upon launching these kites, and affording them abundance of proper line, the uppermost ascended to an amazing height, disappearing at times among the white summer clouds, whilst all the rest, in a series, formed with it in the air below such a lofty scale, as at once changed a boyish pastime into a highly useful Philosophical experiment.

Lord Minto's application of the same experiment.

(362.) The Earl of Minto[*] has somewhat varied the experiment by employing balloons, having register thermometers attached to them, hung freely in a cylindrical case of glazed pasteboard, open at each end. The thermometer below was suspended in a similar case.[†]

On the Plane of Perpetual Snow.

General considerations.

(363.) The preceding researches respecting the progressive diminution of temperature as we ascend through the air, must conduct us at last to a region of perpetual snow. We have proved, at least approximatively, the existence of a law, common to all the regions of the Earth, by which the decrease of heat in the atmosphere is measured, but which, nevertheless, depends, in the extent of its operation, on the different temperatures of the terrestrial parallels. If we go to the Equator, where the maximum mean temperature is found, and trace the law of its descent in the great volume of the air, until it reaches the limit which Nature assigns to the existence of perpetual snow, we shall arrive at an elevation much greater, than if we ascended from the mean Geographical parallel, or endeavoured to trace its limits above the Polar circle. Thus the great heats of the torrid zone influence the temperature of the air at a much greater elevation above the Ocean, than the temperate regions of Europe, or those cheerless climes of the North, where the dominion of cold holds a more unlimited sway.

No animated beings o vegetabl forms ex above it.

(364.) In setting out from the Equatorial regions, where the magnitudes of the mountain masses fill the traveller with amazement and awe, he is led to contemplate those hoary summits, which in so many latitudes invite his examination;—unfolding the existence of a plane—magnificent from its extent and operations—at and above which, all the dreary powers of winter are called into perpetual action; which, even in the torrid zone, destroys the fairest and most gigantic forms of vegetation, and permits within its vast and boundless domain, the existence of no animated being to disclose, amidst the fearful sublimity, those living functions and powers, which communicate happiness and joy to the more favoured regions of the Earth.[‡]

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[*] *Edinburgh Journal of Science*, vol. vii. p. 249.

[†] Lord Minto seems to have enclosed his *lower* thermometer in a case of *writing paper*. The circumstances of an experiment will be much altered by the employment of thermometers enclosed in cases of *different materials*. Dr. Wells has given some interesting observations on this head, in his valuable *Essay on Dew*. When the bulb of a thermometer was enclosed in a metallic paper, the temperature indicated by it was found to be greater than the actual temperature of the air; whereas one enclosed in a similar case of white paper, was commonly found, when a difference did exist, to be lower.

[‡] This observation cannot be regarded as rigidly true; although when contrasting the dreary regions of the perpetual snows, with the

Plane of perpetual snows supposed at first to be uniform,

(365.) By the plane of perpetual snows, we are to understand the curved surface which passes through the greatest heights at which the snows are preserved during the entire year. To trace the altitude of this plane above the different terrestrial parallels, has long been an object of interesting inquiry. At first it was imagined, that its range through the atmosphere partook of some character of uniformity; but later and more Philosophic views have proved, that its altitude above the level of the sea, is the result of a great variety of causes, —of all the uncertain conditions of the terrestrial surface,—of the unequal distribution of heat,—of the anomalous effects of mountains and plains, the great oceans alone contributing a partial uniformity to it.

but now known to be most unequal.

General idea of its figure.

(366.) A general idea of its figure may, however, be gathered from fig. 5, in which N E S Q denotes the surface of the Earth, and C D E F the superior limit of the atmosphere. The curve A N B S may be supposed to represent a section of the plane of perpetual snow, attaining, but for peculiar anomalies, its greatest elevation at A E and B Q in the Equatorial regions, and gradually descending towards the Earth's surface, until it at length meets it in some point of the Polar zone.

Its elevation known but at a few points.

(367.) The known points are comparatively few, which mark the elevation of this plane above the ordinary level of the sea; and they ought to be highly valued, notwithstanding the chances of some uncertainty existing in them, when we consider the immense difficulties attendant on their determination. We shall, therefore, take a rapid review of its position on some of the principal mountain chains of the Globe.

First attempts in Equatorial regions to find its elevation.

(368.) It is in the Equatorial regions of the New World that we meet with the most magnificent examples of this splendid plane, as it was in that region the first efforts were made to ascertain its height. The first and earliest attempt was made by the French and Spanish Philosophers, who were employed in the operations connected with the measurement of the great arc of the meridian in the tropical regions. The measures of Bouguer and Condamine appear to disagree, although an inscription engraven on a table of marble, —which, in spite of the destruction of the Order of the Jesuits, has been preserved in one of the Galleries of the College of that order at Quito,—seems to imply that a common measure was agreed on by these celebrated men: *Altitudo acutioris ac lapidei cacuminis nive plerumque operti 2432 hexapedes Parisienses, ut et nivis infimæ permanentis in montibus nivosis.* Ulloa and Don Juan, coadjutors in the same great enterprise, assigned a different value to the altitude of the plane.

Rocky summits of Pichincha.

(369.) The latest investigations of Humboldt on this very important subject, are contained in an admirable Paper, *Sur la limite inférieure des Neiges perpétuelles dans les Montagnes de l'Himâlaya et les Régions Equatoriales*, and published in the *Annales de Chimie*, tom. xiv. p. 5. The Volcano of Pichincha, he says, has four rocky summits, the altitudes of which were determined by direct barometrical measurements, by angles of elevation taken near Quito, and by trigonometrical operations carried on at Cachapamba, on a plane whose elevation is 8576 feet. His results are contained in

TABLE LXXXVII.

Names of the Summits.	Altitude in feet.
Rucupichincha.................	15924
Huahuapichincha	15719
Cono de los Ladrillos............	15354
Tablauma	15278

One only covered with perpetual snow.

(370.) Of these summits, only the first is covered with snow during the whole of the year, the inferior limit descending from 25 to 35 fathoms below its top. The Huahuapichincha, the next in elevation, is nearly always destitute of snow, its peak seeming just to penetrate the mighty plane of frost.*

Perpetual snows of Chimborazo.

(371.) On the great mountain of Chimborazo, Humboldt found the perpetual snows, by a trigonometrical operation carried on in the Plain of Tapia, near the City of Riobamba-Neuvo, to be at an elevation of 15,802 feet above the level of the South Sea. He also remarks, that the diameter of the mountain where the snows commence, seemed, from measures made at different epochs, to be 22,031 feet—a proof of the nearly equal constancy of their elevation in those regions.†

Cotopaxi.

(372.) On the sides of the Volcano of Cotopaxi, the elevation of this plane was found, by a trigonometrical operation performed in the plains of Mulalo, to be 16,231 feet, although from some other considerations, Humboldt is disposed to regard it as 15,924 feet. This volcanic cone is not well adapted for the determination of the perpetual snows. Its form, however, is described by Humboldt to be the most beautiful and regular of the colossal summits of the high Andes. It is a perfect cone, which, covered with an enormous layer of snow, shines with dazzling splendour at the setting of the sun, and detaches itself in the most picturesque manner from the sky. The covering of snow conceals from the eye of the observer even the smallest inequalities of the soil. No point of rock, no stony mass, penetrates the coating of ice, or breaks the uniformity of the figure of the cone. We have given, in figure 6, a representation of this magnificent mountain, because it affords a good example of the well-defined limits of the perpetual snows.

At times entirely deprived of its snows.

(373.) It is worthy of observation, however, that notwithstanding the enormous bulk of this mountain, it is liable at times to be despoiled of its snowy mantle, by the active agency of its internal fires; and Humboldt, with his usual acuteness, has drawn from this circumstance the useful Geological inference, that its sides are therefore thinner than those of the other

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beautiful fertility of the climates below, an apology may be found for the expression. Wahlenberg, in his observations on the Lapland Alps, observes that the Snow Bunting, *Emberiza Nivalis*, is the only living creature that visits an elevation of 2000 feet above the perpetual snows. It has also been remarked, that the Ansonia butterfly is occasionally found to fly over the very summit of Mont Blanc. Wahlenberg also remarks, that a few plants of *Ranunculus glacialis*, and other similar ones, may now and then be found in the cleft of some dark rock rising through the snow. This happens even to the height of 500 feet above that line. Further up the snow is very rarely moistened, yet some umbilicated lichens, (*Gyrophoræ*,) &c., still occur in the crevices of perpendicular rocks, even to the height of 2000 feet above the line of perpetual snows.

* According to some very accurate measures, the summit of the mountain appears to rise above the plane of perpetual snow only two fathoms.

† See Humboldt, *Rec. d'Observ. Astr.* tom. i. p. 72; and Zach., *De l'Attraction des Montagnes*, vol. i. p. 7.

mountains whose bosoms are the seats of equally active volcanic fires. The disappearance of the snow is regarded by the natives as a certain index of an approaching eruption.*

Mountain of Antisana.

(374.) The Mountain of Antisana is another example given by Humboldt to illustrate the subject of the perpetual snows. On account of its being surrounded, however, at an elevation of 13,429 feet, by a vast plain, exercising great radiating powers, he concludes that the perpetual snows are pushed as a necessary consequence to a higher region in the air. And, although the numerical mean of all the examples recorded, amounts to 15,803 feet, yet Humboldt, making an allowance for the fires of Cotopaxi, and the force of radiation here referred to, is disposed to fix the altitude of the perpetual snows at the Equator at no greater elevation than 15,748 feet, or 4800 metres. The next Table contains the whole of his results.

Altitude of perpetual snows at the Equator.

TABLE LXXXVIII.

Names of the Mountains.	Latitudes.	Altitude of the lower limits of the Perpetual Snows in feet.
Rucupichincha	0° 10′ S.	15700
Huahuapichincha	.....	15732
Antisana	0 31	15943
Corazon	0 32	15719
Cotopaxi	0 41	15924
Chimborazo	1 28	15802
	Mean....	15803

The altitude of perpetual snows at Equator can only be deduced from the Andes.

(375.) The determination of this Equatorial element, although of the utmost importance in any attempt that may be made to trace theoretically the plane of the perpetual snows, must rest entirely on the observations that have been made in the Andes. It is true that we are not yet acquainted with the altitudes of all the mountains of America to the East of Peru, although we are certain the perpetual snows exist in this continent only in the chain of the Andes, of which the Cordilleras of Mexico are to be regarded as a prolongation towards the North, in the group of Merida, and in that of Santa Martha. Not one of the summits of the chain, it may be remarked, on the coast of Venezuela, of those of Parime, of Chiquittos, and of the Brazil, pass above the limit of perpetual snow; and hence Humboldt has remarked, that these snows are wanting in all the Eastern and non-volcanic region of the New Continent. Of the interior of Africa between Cape Lopez and Melinda we know nothing, although the traditions respecting the junctions of the mountains of Lupata, and Al Komri, render it probable that the Equinoctial regions of Africa yield but little in their altitude to the Andes of Quito. The great size, also, of the elevated plains of the continent of Africa, and the immense accumulations of sand in the meridian of Darfour, must have a tendency to elevate prodigiously the inferior limit of perpetual snow by the influence of radiation; and still, according to the best authorities, the mountains of Al Komri pass above this limit. Through all the remaining range of the Equator, not one solitary mountain is presented, to mark the elevation of the plane whose properties we are endeavouring to trace. The phenomena of the perpetual snows is equally unknown in the Galapagos Isles, and even in Borneo and Sumatra, of which the highest peak, the Gunong Pasaman, reaches only to an elevation of 13,842 feet.

The elevated plains of Africa raise the limit of perpetual snows.

Attempts find elev tion of pe petual snows in other lati tudes.

(376.) The determination of the altitude of the perpetual snows in the Equatorial regions, necessarily led to inquiries respecting its altitude in other latitudes; and their observed approximation towards the surface of the Earth, opened a most fruitful field of inquiry. In the immediate vicinity of the Equator, a small change in the latitude was observed to produce no sensible difference; but as observations became extended towards the Northern border of the torrid zone, that difference became perceptible. It is still, however, in the Cordillera of the Andes—of all the mountain chains being the only one prolonged in the direction of a meridian for the extent of 2000 leagues—that we must seek for further elements of this interesting problem. It is true, indeed, that the Cordillera does not offer a continued chain of snowy summits, as the Alps of Swisserland, and the mountains of Himalaya, but it is, nevertheless, raised into seven enormous groups to the North of the Equator, at a prodigious elevation.

Humbold measurements of perpetual snows on mountain of Mexic

(377.) With respect to observations made at the Northern extremity of the torrid zone, the most perfect are those by Humboldt on the elevated plains of Mexico. On the parallel of the great heights of Anahuac, between 18° 59′ and 19° 12′ of North latitude, six enormous mountains are ranged in the same East and West line. Four of these mountains, *viz.* the Peak of Orizaba, having an altitude of 17,375 feet; that of Popocatepetl, of 17,722 feet; that of Iztaccihuatl, or the White Woman, exceeding 15,028 feet; and the Nevado de Toluco, of 15,169 feet; are perpetually covered with snow. Two others, however, the Cofre de Pérote, having an elevation of 13,417 feet, and the Volcano of Colima, exceeding 10,871 feet, are often destitute of snow the greater part of the year. According to a trigonometrical measure made by Humboldt on the snows of Popocatepetl, in latitude 18° 59′, in the month of November, the inferior limit was found at an elevation of 14,977 feet; but by calculating the barometric observations of M. Sonneschmidt, according to the formula of La Place, the altitude obtained was 15,163 feet. An application of the same formula to some observations of d'Alzate, gave for the altitude of the snows of Iztaccihuatl, in 19° 10′ of North latitude, 15,060 feet. Humboldt by an observation, on which, however, he does not much depend, assigned to this elevation only 14,069 feet. The Nevado de Teluco, in lat. 19° 11′ North, presents, like Rucupichincha, an immense central hollow, surrounded by rocks of a turretted form, and of a very dangerous access. Like Rucupichincha, also, the summit of the Nevado but just enters the limit of the perpetual snows.*

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* In January, 1803, eight months after Humboldt and Bonpland's visit to Cotopaxi, it threw forth enormous volumes of fire and scoriæ, and the catastrophe was preceded by a total melting of the snow.

* Humboldt carried his barometers to the most elevated summit (Pico del Fraile) where he found the surface of the rock pierced and vitrified by the effect of atmospheric electricity. This phenomenon, according to Mr. Gilbert, is analogous to that of the hollow cylinders

General inferences respecting snows of Mexico.

(378.) From the whole of the observations made and collected by Humboldt in this interesting region, he draws the conclusion, that in the nineteenth degree of latitude, the plane of the perpetual snows is found at an elevation of 15,028 feet, or at the lowest estimate 14,708 feet. On the borders of the torrid zone, therefore, this plane has only lowered 720 feet, or at most 1040 feet; but it should at the same time be remarked, that the *Nevados* of Mexico are encompassed by an arid plain, which radiates heat powerfully, and of which the mean temperature is 62°.6, and in which, during the hottest months, the thermometer ranges by day between 60°.8 and 69°.8, and through the night from 55°.4 to 59°.0. This country is not, like Quito, a narrow valley contained between two chains of the Andes, but a country elevated in one enormous mass, to an elevation of twelve or thirteen hundred toises.

Mountains of Himalaya.

(379.) From the latitude of 19° to the parallel of 30°, we are not acquainted with the altitude of a single snowy peak. Of the mountains of Mexico, not one peak penetrates the plane of the perpetual snows between the parallels of 19° 12′ and 40° North. The Peak of Teneriffe can hardly be said to reach it, and we are not acquainted with the interior of New Holland. A portion of the zone, however, in the Eastern hemisphere, comprised between the latitude of 27½° and 36°, embraces the stupendous range of the Mountains of Himalaya—those holy haunts of superstition, where, enthroned on lofty and snow-capped pinnacles, the divine Mahadeo sits and surveys the fertile plains of Hindústan.*

Earliest estimate of their altitude made by Mr. Colebrooke.

(380.) Some of those extraordinary men, the Jesuit Missionaries, were the first in modern times to scale this stupendous buttress; and although the British conquerors of India had long contemplated the snowy summits from the plains of Hindústan,† yet many years have not elapsed since we were ignorant of all but the general name of this vast mountain range. The earliest estimate of the altitude of one of its "conspicuous peaks" was made by that very able and accomplished scholar Mr. Colebrooke, in the year 1790, when he deduced, from observations made at a station in Bengal, an altitude of 26,000 feet. The subject was afterwards resumed by the same author in the year 1814, in the *Asiatic Researches*, and in which he examined with great acuteness and ability the information then existing; and announced, for the first time, that the Indo-tartaric Mountains surpass the Cordillera of the Andes, before esteemed the highest on the Earth. This, indeed, had long been suspected; or, rather, as Mr. Colebrooke observes, had been very generally believed in India; for Major Rennel had remarked, in one of his able *Memoirs*, that the distance at which these mountains could be viewed from the plains of Bengal exceeded 150 miles; and a simple computation applied to the actual dimensions of the Earth would naturally afford some inference of the kind.

Observations of Captain Webb.

(381.) In November, 1817, Captain Webb, who had been engaged in the important operation of surveying the Ganges to its remotest accessible source, published a Memoir on the same subject, containing the measurements of more than two hundred elevated positions, determined geometrically for inaccessible heights, and by the same mode combined with the barometer, for those stations that were found capable of access. By tracing also the *Gauri* River to the place where it emerges from the snow, at the elevation of 11,543 feet, he furnished the first element afforded by this interesting inquiry on the subject of the perpetual snows. A copious abstract of this part of Captain Webb's labours, will be found in the VIth Volume of the *Journal of the Royal Institution*, drawn up by Mr. Colebrooke, with his accustomed perspicuity, and intended probably as a reply to the objections that had been made to the former measurements of Captain Webb in the XXXIVth Number of the *Quarterly Review*. It is worthy of Historical notice, that the Number of the *Review*, containing the objections to the measurements of Captain Webb, was received by him at the Temple of Kedar-nath,* a spot which had never before been visited by any European. Animated by a truly Philosophic spirit, he determined to recommence his admeasurements, and, if possible, to verify or refute the conclusions of the reviewer on the spot; a task which he well knew his barometers would enable him to effect.

Determination of altitude where the Gauri River emerges from perpetual snows.

Mr. Colebrooke first announced that the inferior limit of snows is higher than theory gives.

(382.) But little, however, had been hitherto advanced in all these discussions, connected with the main object of this division of our Essay. The subject of the perpetual snows had only been glanced at as part of a magnificent picture, until Mr. Colebrooke published, in the VIIth Number of the *Journal of the Royal Institution*, an Essay on the Limit of Constant Congelation in the Himalaya Mountains, derived from the Observations of Captain Webb; and for the first time remarked, that the inferior limit of perpetual snows does not descend so low as theory would lead us to conclude. This was followed up by Humboldt's Memoir on the Mountains of India, and by an Essay in the XLIVth Number of the *Quarterly Review*, on the passage of the Himalaya chain. In the XIVth Volume of the *Annales de Chimie*, Humboldt published the admirable dissertation before alluded to, on the inferior limit of the perpetual snows in the Himalaya Mountains, in which he discussed the latest observations of Captain Webb, and remarked with respect to the anomalies they present, that the more the results seem to be opposed to the conclusions deduced from the snows of the Andes, the more ought they to fix the attention of Philosophers.

Humboldt's investigations on the same subject.

Captain Webb's confirmation of great anomalies discovered by him.

(383.) It will be useful, therefore, to follow a few of the steps of Captain Webb in this interesting inquiry, in order to make our readers acquainted with some of

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of vitrified earth, which have been recently found in the sands of Germany and other places, and which will be more particularly alluded to hereafter.

* The mountain which is held to be the throne, or residence, of Mahadeo has five principal peaks, called Roodroo Himala, Burrumpooree, Bissinpooree, Ordgurreekauta, and Soorga Rounee. These form a sort of semicircular hollow of very considerable extent, filled with eternal snow. Mr. Baillie Frazer was the first European that ever penetrated to the holiest shrine of Hindú worship which these stupendous mountains contain.

† These mountains appear from the plains of Bengal in the distant horizon, extending in a continued line through more than two points of the compass, and appearing in clear weather like white cliffs, with a very distinctly defined outline.

* Kedar-nath is one of those numerous shrines, which neither difficulties nor dangers, mountain roads, fierce torrents, or steep precipices can deter the pilgrim from visiting, in order to perform those duties which are enjoined by the Hindú Religion,—a Religion which seems to delight, as Captain Webb justly observes, in practically demonstrating to its deluded votaries, that rugged as is the path to that region of beatitude to which in fancy they are continually pressing forward, its ministers endeavour, by every means which human ingenuity can devise, to render it yet more intolerable by wantonly strewing it with additional thorns.

the enormous deviations of the snow line on the mountains in question, from all the theoretical deductions that had been previously made.

Great elevation of Milem without snow.

Also the ridge of mountains to the South of Dauli river.

(384.) The village and Temple of Milem were found by this enterprising surveyor at the respective elevations of 11,405 and 11,682 feet above Calcutta; extensive fields of buck wheat and Tartaric barley occupying the space between the two. A twelvemonth after these observations were made, *viz.* on the 21st of June, 1818, Captain Webb proceeded Southward from Jóshí-mat'h, and from the Dauli River, observed barometrically the altitude of a station on the ridge of mountains to the South of that river. Its altitude he found to be 11,680 feet above the level of Calcutta, yet the place was surrounded by flourishing woods of hoary oak, long-leaved pine, and arborescent rhododendron, and the whole surface clothed with a rich vegetation as high as the knee, extensive beds of strawberries in full flower, and plenty of currant-bushes in blossom all around, in clear spots of rich black mould.

Also the pass of Pilgointi Churhaï.

On the following day Captain Webb reached the summit of the pass Pilgointi Churhaï, and found its elevation to be 12,642 feet above the same level, or more than 12,700 feet above the sea. A thick mist confined the prospect, but no snow was to be seen contiguous to the spot. The surface exhibited a black soil, unless where the bare rock appeared, covered with strawberry plants, butter-cups, dandelions, and a profusion of other flowers. Even a projecting part of a higher mountain was destitute of snow, and, as far as the view extended, it appeared enamelled with flowers. The goatherds of the country are accustomed to lead their flocks to pasture during the months of July and August upon a yet loftier ridge, estimated to be as much above the pass of Pilgointi, as this was above the preceding day's encampment; that is, nearly a thousand feet, and which therefore removes the actual boundary of congelation to a still higher elevation.

Snows not perpetual at 12,000 feet on Southern side, in lat. 30° 40′.

(385.) The Temple of Kedar-nath before alluded to, according to a mean of five barometrical observations, is 11,897 feet above Calcutta, or 12,000 feet above the level of the sea; but no snow remained in the vicinity of the Temple later than the beginning of July; so that under the latitude of 30° 40′, at the last-mentioned elevation, the snows were not perpetual on the *Southern* side of the Himalaya Mountains.

Remarkable example afforded by Nitee Ghaut.

(386.) Another remarkable example is afforded by Captain Webb's observations on the crest of the Nitee Ghaut. On the 21st of August, at 3 P. M., four barometers gave a mean elevation of the quicksilver equal to 16.27 inches, the temperature at the same time being 47°. From a Journal kept by General Hardwicke at Dumdum, about fifty feet above the sea, the mean of five observations, of which that on the 21st of August formed the middle term, gave for the barometric pressure 29.51 inches, and for the average temperature 84°.4. These comparative results, after allowing for the height of Dumdum, gave for the total elevation of the Nitee Ghaut above the sea, 16,814 feet. At this great elevation not a vestige of snow was to be seen on the Ghaut, nor on the projecting shoulder of the mountain ridge, rising about 300 feet on the Western side of the pass; and we may hence conclude from it, that the height of the lower limit of congelation, on the *Northern* side of the Himalaya range, cannot be less than seventeen thousand feet.

Lower limit of congelation on Northern side not less than 17,000 feet.

Great e vation Table of Tartary, d tute of petual snow.

(387.) The great elevation of the Table Land of Tartary is deserving also of much consideration in an inquiry of this nature, influencing, as all extensive plains do, every circumstance of temperature. By observations made on the crest of the Nitee pass, Captain Webb found the Sutledge to flow in a plain elevated 14,924 feet above the level of the sea; yet so far are the great plains known to the Hindús by the name of Undes, or Oondes,* from being buried in eternal snow, as our ordinary theories would lead us to suppose, the banks of the river afford the finest pastures for myriads of quadrupeds throughout the year. The town of Daba, also, which Moorcroft asserted to be only a summer residence, appears to be tenanted in all seasons. In the neighbourhood of this place, and near Doompoo, both considerably higher than the bed of the Sutledge, Captain Webb was informed that the finest crops of a grain called *Ooa* were gathered, from which the natives make their bread.

Captai Gerard found c tinuous snow-b comme ing at 16,300

(388.) Captain Gerard observes, in his surveys published in the Ist volume of the *Transactions of the Royal Asiatic Society of London*, that when proceeding by the Chárang pass, 17,348 feet high, to the valley of Nangaltí, many snow-beds were crossed, and that, at about the height of 16,300 feet, the "continuous snow-beds commenced." In another place, however, he remarks that the mountains in the neighbourhood of *Chárang* are all of blue slate, naked to their tops, and exhibiting decay and barrenness in their most frightful forms. They tower in sharp, detached groups to about 18,000 feet; no vegetation approaching their bases, nor do their elevated summits offer any rest to snow.† Upon the left bank of the *Táglá* river, mountains of an elevation of 16,000 feet are found, on which no snow appears. Upon the right bank, the summits seem to be 18,000 feet, and with but little snow in streaks. The mountains also which enclose the dell of the Táglá river, are between 19,000 and 20,000 feet in elevation, and but just tipped with snow.

Remar altitude perpetu snows Northe and So ern sid Himal chain.

(389.) A proof, likewise, of the disparity between the altitudes of the perpetual snows on the Northern and Southern sides of the Himalaya mountains may be gathered from the following remarks of Captain Gerard. Zamsírí, a mere halting-place for travellers, on the banks of the Shéltí, is 15,600 feet above the level of the sea, a height equal to that of the passes through the outer range of the snowy mountains, and yet, he says, there is nothing to remind the traveller of the Himalaya. Gently sloping hills and tranquil rivulets, with banks of turf and pebbly beds, flocks of pigeons, and herds of deer, present the idea of a much lower elevation. But Nature, continues Captain Gerard, has adapted the vegetation to this extraordinary country; for did it extend no higher than on the Southern face of the Himalaya, Tartary would be uninhabitable both by man or beast. On ascending the *Southern* slope of the snowy range, the extreme height of cultivation is found at 10,000 feet, and even there the crops are frequently cut green. The highest habitation is 9500 feet, and 11,800 feet may be reckoned the upper limit of forests, and 12,000 that of bushes, although, in a few sheltered situations, dwarf-birches,

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* Signifying the *Region of Wool*. It is from this lofty region the Cashmír manufacturers are chiefly supplied with the material from which their celebrated shawls are made.

† It is possible that their great steepness may prevent the snow from resting on them.

and small bushes are found almost at 13,000 feet. But if we go to the Baspă river, the highest village will be found at an elevation of 11,400 feet, cultivation reaching to the same altitude, and forests extending to 13,000 feet at least. Advancing further, we find villages at the last-mentioned elevation, cultivation 600 feet higher, fine birch-trees at 14,000 feet, and támá bushes at 17,000 feet. Eastward, towards Mánassaróvai, according to the accounts of the Tartars, crops and bushes thrive at a still greater height.

Perpetual snows depend much on influence of localities.

Difficulty of the anomalies presented by snows of Himalaya chain.

(390.) From the preceding observations it is apparent, that excepting the determination of the spot from which the Gauri river emerges from the snow, and the observations made at the Chárang pass, no direct barometrical observations have yet been made at the actual elevation of the perpetual snows on this magnificent range. The determinations that have been made connected with the elevated points and plains on which the perpetual snows are never found, afford only indirect evidence on the subject, but yet are sufficient to awaken the most ardent curiosity respecting the deviations which this region presents, from all our previously received notions respecting the positions of the perpetual snows in the latitudes referred to. Humboldt has truly remarked, that of all the phenomena connected with the distribution of heat, no one is more complicated, or more dependent on the influences of particular localities, than that of the perpetual snows; and it is not too much to say, in the present condition of our knowledge, that we are unable to account satisfactorily for the extraordinary anomalies we have alluded to. That the great elevation of the plane of the perpetual snows, in the regions referred to, is an effect of a very copious radiation of heat from the elevated plains of Tartary, is certain; but, unless we are able to assign a numerical value to this radiating power, we are deprived of every means of tracing its effects on the higher regions of the air. We know, indeed, too little of the nature of terrestrial radiation, to attempt to form an estimate of its influence, when developed on so great a scale as in the plateaus referred to. We know but little of the effects of declivities in modifying the circumstances of temperature; or of the influence that the very nakedness of the soil may exercise on the air which reposes on it; nor can we attempt to measure the play of the currents which descend from the neighbouring summits, or to trace the effects of the humidity of the forests which lie scattered at their base. Added to this, we know that the summers are exceedingly short, commencing about the middle of June, and ending about the middle of August, scarcely ever extending to the close of that month; a circumstance which adds new conditions of difficulty to the whole inquiry. So early as the 10th of August, we are told by Mr. Moorcroft, the thermometer in the morning fell to the freezing point, and his tent was covered two inches thick with snow; and on the 28th, near the Nitee pass, the mercury stood at 28°, ice being formed $2\frac{1}{2}$ inches thick. The fact, also, of the ripening of grain at so great an elevation, seems to favour Mr. Daniell's opinion of the superior energy of the solar rays in the higher regions of the air. We know, indeed, that on the Southern side of the Himalaya chain, at an altitude of eleven or twelve thousand feet, the temperature varies during the hottest part of the day from 60° to 75° in the shade and during the night descends not lower than 50° or 45°; the sun developing its whole power during the day, and a shower of rain but rarely falling.

Effects of grouping of mountains.

Where isothermal lines at the surface have convex summits, perpetual snows are higher.

(391.) Humboldt has likewise remarked, that if all the mountains covered with eternal snow, instead of being connected together in continued chains, or supported by table land of a greater or less extent, formed insulated cones of equal dimensions, it is probable that the limits of the perpetual snow, under different meridians, would preserve a constant elevation above an isothermal line traced at the level of the sea; and did such cones exist, the altitude of the perpetual snows might enable us even to estimate the measure of the summer heat in the plains below. But as the isothermal lines have convex summits in the interior of a large continent, and as the temperature of the summer in such a region exceeds that which otherwise the conditions of latitude would afford, the perpetual snows must attain a corresponding excess of elevation. Besides this effect of the radiation of the summer heat of the plains, there are also other causes operating in the higher regions of the air, which, together with the peculiar conformation of mountains, unequally raise or lower the limit of constant snow above the same isothermal band. Humboldt sometimes met with heats in the middle of the Andes, equivalent to those of the plains, and which he found to be more insupportable, because the air of valleys of that kind is but seldom agitated by the winds.

Final remarks on Himalaya chain.

(392.) Finally, it is to be observed respecting the mountains of India, that they occupy a position in a considerable degree central, and in consequence have what has been denominated a continental climate; that is, summers exceedingly hot, and winters very cold. In a climate of this nature it is also found, that comparatively but little snow falls, when the air is cooled below 10° of temperature. The snows are, therefore, not necessarily thicker, where the winters are more rigorous, or where the atmosphere passes rapidly to its extreme degree of cold. If, says Humboldt, the curves of equal annual temperature, when traced on the plains, have a concave summit in Asia, the lines of equal summer, on the contrary, are raised considerably; and where this is the case, anomalies like the present must exist. And when we consider that the enormous range of mountain and table land, the influences of which on the atmosphere we have been endeavouring to trace, exceeds 800 leagues in length, and 400 leagues in breadth, disclosing in the whole extent of its surface, a quantity exceeding 3,266,500 square British miles, we cannot but expect that a mass, so extraordinary from its magnitude and position, should disclose phenomena connected with climate, the numerical effects of which cannot be estimated in the present condition of Meteorological science.

Snows of Caucasus higher than those of the Pyrenees, although nearly in same latitude.

(393.) The chains of Caucasus and of the Pyrenees occupy nearly the same average latitude, and a comparison of the perpetual snows in the two ranges discloses a very interesting fact. Mount Kasbek, in the first of these chains, is scarcely half a degree more South than the Pyrenees, and yet the perpetual snows are supported on its Northern slope, according to the barometric measurements of Englehardt and Parrot, at an elevation of 10,552 feet, whereas in the range of the Pyrenees, as we shall presently see, Ramond estimated this limit so low as 7674 feet; and if we adopt the higher elevation given by Hum-

Cause of great elevation of snows of Caucasus.

boldt, we shall still find a difference of 250 or 300 fathoms in the small range of half a degree of latitude. The cause of this anomaly is to be attributed to the peculiar position of this mountain chain; partly from its being situated in a narrow isthmus between two seas, but principally from the effects produced on its temperature by the very extensive plain which ranges from its base through Moscow to the Icy Sea. And that an increase in the altitude of the perpetual snows may be reasonably inferred from the latter cause, may be gathered from the great elevation of the isothermal curves in this continent. Humboldt remarks, that at Moscow, in latitude 55° 45′, and on the isothermal line of 40°.1, the temperature of the hottest month rises to 70°.5; whereas at Paris, in latitude 48° 50′, on the isothermal line of 51°.1, the warmth of the hottest month amounts in general but to 65°.3.

Altitude of perpetual snows on Pyrenees.

(394.) The altitude of the perpetual snows on the mountains of the Pyrenees, is differently reported by different authors. By Humboldt their elevation is stated at 1400 fathoms, but according to Ramond, their general range commences at 7674 feet, and presents a snowy band of 500 or 600 fathoms in breadth. These mountains are very abrupt, and numerous snow-fields exist, some of which are of considerable extent; and Ramond has deduced from them a most interesting fact, that the snow-line along the breadth of the mountains constitutes a curve whose convexity is turned towards the Earth, and whose apex is probably at a middle distance between the opposite sides of the range. This flexure in the perpetual snows arises from a twofold cause. The warm air ascending the sides of the mountains has a tendency to elevate the plane of the perpetual snows; whereas the chilling influence of the great fields of snow, causes its middle portion to descend; so that instead of preserving its continued concavity, as A B fig. 7, it presents a convex section, as C D. The observations of Ramond were principally directed to *Mont Perdu*, and he remarks, that snow exists from the great glacier to its summit; but that the thickness gradually diminishes, and becomes very inconsiderable towards the top, on account of its trenched form not admitting of any great accumulation. On the Northern side, the snows obtain, by degrees, an extraordinary consistency; but on the Southern, the soil can be readily distinguished; a fact, however, which Ramond is disposed to attribute less to the action of the solar heat, than to the extreme precipitancy of that part of the mountain pass.*

Flexure in the plane of perpetual snows.

Difference in snows of Northern and Southern sides of Pyrenees.

Snows of the Alps

(395.) Saussure, in his most interesting journey, fixes the limit of perpetual snow in the Alps at 8313 feet, or 9273 feet, or at a mean elevation of 8793 feet. We know, also, that very considerable differences exist in the altitudes of the perpetual snows on the Northern and Southern sides of the Alps. Of Mont Blanc, it may be remarked, that the mantle of snow which covers its top exceeds in elevation 4000 feet, and occupies horizontally an extent of 9000 feet; the total height of the ice and snow, estimated from the source of the Arveron, at the bottom of the glacier of Montanvert, to the summit of the mountain, being not less than 12,000 feet in perpendicular height. According to Von Buch, the altitude of the snow-line between the parallels of 45¼° and 46½°, amounts to 9080 feet; and that in Appenzel it must be 100 fathoms lower than in the Valais and in Savoy, and cannot exceed 8402 feet.

Saussure made an ingenious estimate of the refrigerating influence of the great snow-fields which exist in the Alps, in sinking the line of the perpetual snows, and found it capable of depressing their range 600 feet below its level, even on the lesser mountains of the Alps. Both Ramond and Saussure have remarked the chilling influence of these snow-fields in producing contrary flexures in the snow-lines of the Alps, as in the case of the Pyrenees. These flexures may in some cases be very numerous and varied. Thus, in a group of elevated peaks, as in fig. 8, if vertical planes be supposed to pass from the peak A to the summits denoted by B, C, D, and E, through the curve of the perpetual snows, a series of sections may be presented of an exceedingly diversified character, arising from the unequal radiating powers of the surfaces below. And these inequalities will be found not only to exist on the innumerable surfaces of a great mountain range like the Alps, or the Andes, as rendered visible by the snows with which they are covered, but inequalities somewhat analogous must exist in the atmosphere above those mountains whose summits do not reach the range of perpetual snow. A hot valley will have a tendency to raise it,* whereas a snow-field will exercise an opposite effect. The flexures of the perpetual snows, also, in the atmosphere of a level country like Russia, must be of a much less variable kind than in the mountainous regions of Norway or Swisserland. The plane of the perpetual snows is most uniform over the Ocean.

Saussure's ingenious estimate o their refrigerating i fluence.

Perpetual snows mo uniform o the Ocea

Carpathi mountain

(396.) The Carpathian mountains, also, present some interesting anomalies connected with the snow-line. Occupying a position between the parallels of 48° 55′ and 49° 15′, and extending through a degree and a half of longitude, they exercise, in conjunction with the neighbouring plains, a considerable influence on Meteorological phenomena. Although situated to the North of the Alps, the perpetual snows are found at a much higher elevation than on the mountains of Swisserland. Mont Pilatus, for example, in the latter Country, although only 6927 feet above the sea, is covered with perpetual snow; whereas not one of the peaks of the Carpathian range is found to be so, though the great Lomnitzerspitze attains an altitude of 8464 feet. From different considerations, Wahlenberg† supposes that if this mountain had an elevation of 8526 feet, it would just reach the snow-line. Snow lies, indeed, during the whole year, in some of the gullies and chasms of these mountains, and there is a kind of glacier at Eisthalerspitze, arising from this cause. This anomaly in the elevation of the snow-line is to be attributed to the hot winds from the plains of Hungary, which being by far the most extensive in Europe, and situated considerably to the South, the heat in summer is very great. A confirmation of this anomaly is afforded in the vegetation of the Carpathian range. Corn and

Althoug North of Alps, the snows ar much hig than on mountai of Swiss land.

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* This interesting geological feature exercises an important influence on the problem of the perpetual snows, nor is the observation to be confined to the mountains of the Pyrenees. The Alps, like them, are steepest to the South, but the mountains of Scandinavia have their most precipitous sides on the North.

* May not large towns have a tendency to raise the plane of snows above its proper elevation, from the currents of warm air almost constantly ascending from them? Howard remarks, that London is always warmer than the neighbouring country at a mean rate by more than a degree and a half.

† Wahlenberg on the Carpathian Mountains. Göttingæ impensis Vandenhöck et Ruprecht 1814.

fruit trees flourish at a greater elevation on the outskirts of these mountains, than in Swisserland, and the ~~region of beeches is much richer in plants than the same~~ region in the range of the Swiss Alps.

Few examples of perpetual snows in Sweden, but many in Norway.

(397.) Of the Scandinavian peninsula it may be remarked, that Sweden, according to Von Buch, presents ~~few examples of mountains~~ upon which the snow rests in summer; but Norway, consisting of a range of mountains extending from one of its extremities to the other, presents many examples of the perpetual snows. Esmark was the first to direct the attention of the Philosophic world to their range and elevation; but it is the later labours of Von Buch, Hagelstam, and Schouw, that have fixed their limits with accuracy.

(398.) According to Hertzberg the altitude of the snow-line on Folgefonden is 5115 feet; and, although in the entire extent of this mountain range there occur no separate eminences, the whole forming one immense mass of snow without division or valley, there nevertheless occur many diversities in the altitude of the perpetual snows, which it may be proper to advert to. The Melderskin and Solen-Nuden present examples of sudden depressions of the snow-line. The absolute elevation of the former mountain is 4860 feet, and of the latter 4796 feet, and the summits of both are covered with everlasting snow. Flakes of snow lie even upon Age-Nuden, although its altitude is only 4587 feet. Von Buch attributes these changes to the influence of the neighbouring sea. The almost constant fog, says he, which shrouds the outermost islands, the canopy of clouds covering the sky, and the thick rains which exclude the influence of the sun from the ground, occasion the temperature of the summer months, during which alone the snow never melts, to be much less than in regions further removed from the sea. As we pass, however, from the snow-field of Folgefonden, the perpetual snows ascend, and after allowing for all the circumstances connected with it, Von Buch is disposed to regard the mean altitude of the snow-line, in the latitude of 61°, at 5542 feet.

Variation in altitude of snows.

(399.) According to Wahlenberg, the altitude of Sulitelma is 5675 feet, and that of the perpetual snows on its sides 3837 feet. In the latitude of 70°, Von Buch assigns to them an elevation of 3517 feet; but between Alten, to which this elevation belongs, and Hammerfest upon the Island of Qualoe, in the neighbourhood of the great Ocean, the snow-line sinks to 2345 feet; affording the remarkable example of a depression of 1172 feet in an interval but little exceeding a degree; whereas between Fillefieldt and Alten, occupying ten degrees of latitude, the perpetual snows sink but 2025 feet.

Remarkable depression of snow-line.

(400.) We have entered in the succeeding Table the later observations of Hagelstam and Schouw* on this subject, and we shall, therefore, merely observe, that, according to the latter, the snow-line is lower on the Western than on the Eastern side of the Scandinavian chain, by 1000 feet in latitude 67°, and 490 in 60°.† This is, perhaps, not exactly what might have been expected from the greater mean coldness of the Eastern side, nor does Professor Schouw explicitly assign the cause. Dr. Brewster, however, thinks it to arise from the greater range of temperature existing on the side most distant from the Ocean subjecting it to a high temperature in summer, which is the principal cause in the reduction of the snow-line, notwithstanding the greater intensity of the winter frost.

Snows lower on the Western than on the Eastern side of the Scandinavian chain.

(397.) The following Table contains a recapitulation of the whole of the preceding results.

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[*] The observations of Schouw are contained in his *Specimen Geographiæ Physicæ Comparativæ*, a Work which promises to be of the greatest importance to Science.

[†] Dr. Brewster suspects a misprint in the Memoir where the latter number is called 1400, which is not the difference of the heights as printed in the text, unless 4340, the height of the snow-line on the Eastern side, is a mistake as very possibly it may be, for 5340.

With respect to the difference in the altitudes of the snow-line on the Eastern and Western sides of the mountains of Scandinavia, it is worthy of remark, that similar differences are observed with respect to the final limit of trees.

Table LXXXIX.

	Name of the Place.	Latitude.	Altitude of lower limit of Perpetual Snows in feet.	Name of the Observer.	Remarks.
The Andes.	Chimborazo	1°28′ S.	15802	Humboldt.	
	Cotopaxi	0 41 S.	15924	Ditto.	Affected by volcanic fires.
	Corazon	0 32 S.	15719	Ditto.	
	Antisana	0 31 S.	15943	Ditto.	Affected by the radiation of a vast plain.
	Rucupichincha	0 10 S.	15700	Ditto.	
	Huahuapichincha	?	15732	Ditto.	
	General result for the Equator	0 0	15748	Ditto.	
Cordilleras of Mexico.	Popocatepetl	18 59 N.	14977	Ditto.	
	Ditto	18 59	15163	Sonneachmidt.	Deduced from observations by the barometric formula of La Place.
	Iztaccihuatl	19 10	14069	Humboldt.	Doubtful.
	Ditto	19 10	15060	D'Alzate.	Deduced from observations by the barometric formula of La Place.
	From whole of observations made in Mexico	19 0	15028 or 14708	Humboldt.	
Himalaya Mountains in Asia.	Gauri river	30 25	11543	Capt. Webb.	Uncertain whether to be regarded as exact limit of perpetual snow.
	Nitee Ghaut	?	17000	Ditto.	This is the estimated altitude on the Northern side, below which the perpetual snows do not reach.
	Chárang pass	?	16300	Capt. Gerard.	
	Mountains enclosing Dell of Táglá River	?	From 19000 to 20000	Ditto.	Just tipped with snow.
Asia.	Caucasus	42½	10552	Englehardt, and Parrot.	Measured on the Northern slope of the mountains.
European Mountains.	Pyrenees	42¾	8400	Humboldt.	
	Ditto	42¾	7674	Ramond.	
	Alps	45½ to 46	8313 to 9273	Saussure.	
	Ditto	45¾ to 46½	9080	Von Buch.	
	Appenzell	47	8402	Ditto.	Somewhat doubtful.
	Carpathian range	48 55′ to 49 15′	8526	Wahlenberg.	No mountain in this range actually reaches the perpetual snows, though the Lomnitzerspitze has an elevation of 8464 feet, and from the circumstances of temperature attending it, Wahlenberg infers the altitude of the perpetual snows to be but little above it.
	Mountains of Sweden	59	6000	Hagelstam.	
	Mountains of Norway	59 to 60	5800	Ditto.	
	Ditto	59 to 60	5200	Schouw.	
	Folgefonden	60	5115	Hertzberg.	
	Ditto	60	5000	Hagelstam.	
	Melderskin	......	4860	Ditto.	The snow-line is in reality lower than these numbers denote, on account of their representing the altitudes of the mountains themselves. The depression of the snow-line is remarkable.
	Solen-Nuden	......	4796	Ditto.	
	Age-Nuden	......	4587	Ditto.	Flakes of snow lie only on the latter mountain.
	Mountains of Norway	60 to 61	4747	Schouw.	
	Mountains of Sweden	61	5800	Hagelstam.	
	Mountains of Norway	61	5542	Von Buch.	
	Fillefieldt in Norway	61	5600	Hagelstam.	
	Langfieldt in Norway	61 to 62	5410	Ditto.	
	Mountains of Norway	61 to 62	5083	Schouw.	
	Above the Doorefieldt	62 to 63	5300	Hagelstam.	
	Mountains of Norway	62 to 63	5142	Schouw.	
	Mountains of Sweden	63 to 64	5200	Hagelstam.	
	To the West of Fjällrygg in Norway	63 to 64	4800	Ditto.	
	Mountains of Norway	63 to 64	4925	Schouw.	
	Mountains of Sweden	65	4800	Hagelstam.	
	Ditto	67	4400	Ditto.	
	Sulitelma	67	3837	Wahlenberg.	
	Mountains of Norway	67	3600	Schouw.	
	Nordland in Norway	67 to 68	3900	Hagelstam.	On the mountains.
	Ditto	67 to 68	3300	Ditto.	On the coast.
	Alten in Norway	69 to 70	3600	Ditto.	
	Mountains of Norway	70	3517	Von Buch.	
	Ditto	70	3300	Schouw.	
	Hammerfest	71	2345	Von Buch.	
	Mountains of Norway	71	2200	Schouw.	
	North Cape	71 10′	2400	Hagelstam.	

Oscillations in altitude.

(402.) Such are the lower limits[*] assigned to the altitude of this magnificent plane, by the celebrated men whose names are recorded in the Table. If, however, we stop our inquiries at this point, we shall leave many interesting portions of the problem unresolved. The plane of the perpetual snows does not maintain a constant elevation in the same latitude, but varies with the vicissitudes of the seasons, rising during the heat of summer, and sinking by the cold of winter; changing also from one summer to another, as alterations are experienced in the temperatures below.

Andes.

(403.) If we first direct our attention to the Equatorial regions, we shall discover some small oscillations to exist in the altitude of the perpetual snows. To the mountaineers[†] of the Andes, the limit of the perpetual snows presents a phenomenon of a very constant kind; and to their uncultivated minds, the silvery line seems to run through the enormous groups of their mountains, in one continued horizontal plane: the greatness of the distance preventing them from observing those small oscillations of altitude, which the more refined inquiries of the Philosopher have disclosed. This close approximation to uniformity arises from the equality of temperature existing in the different strata of the atmosphere; and accordingly it is found that the utmost amount of the oscillation of the perpetual snows in these regions does not exceed 30 fathoms,[‡] and at the Equator itself rarely amounts to half that quantity. It is often, indeed, insensible, notwithstanding the small differences of temperature which are found to exist between the season of rain and that of great dryness.

Mountains of Mexico.

Himalaya.

(404.) If we pass, however, from the Equatorial regions, we shall discover new conditions presented for investigation. No longer confined to the feeble oscillations we have referred to, we shall find all the attendant phenomena become more irregular. In the mountains of Mexico, the oscillations will be found to amount to 2405 toises, attaining their maximum in January, and their minimum in September;[§] and, although we are not acquainted with the actual extent of the oscillations on the mountains of Himalaya, we may infer from the observations of Captain Hodgson, that they must be considerable. The great cedar pines, those gigantic sons of the snow, says he, fringe the bare rocks, and fix their roots where there appears to be but little soil; and the avalanches bring down whole forests in their overwhelming course, and dash the cedars into splinters.

Striking vicissitudes in temperate zone.

(405.) But much more striking vicissitudes will be found as we advance into the temperate zone. Fields of snow of an enormous width are alternately melted and congealed, creating in the lapse of time those mighty glaciers, which by their varied and gigantic forms impart so much sublimity to the Alps.

Glaciers.

Of the Alps.

(406.) In order that glaciers should exist on a mountain, it must rise considerably above the limit of the perpetual snows. Prodigious masses of ice are also necessary for their formation, and an enormous pressure must act from above, to force the inferior parts of the icy volumes into the valleys below. Hence the frozen masses precipitated by an avalanche, form groups below the lower limit of perpetual snow. In this position they undergo but little change during the lapse of centuries; the alterations produced by the gradual thaw being more than compensated by other masses formed in the cold repositories above, and thence precipitated to the valleys below. Hence it is that travellers have remarked the successive invasions of the Valley of Chamouny, by the avalanches that have descended from Mont Blanc and the adjoining peaks. It is worthy, also, of remark, that the five glaciers which have forced their way into the beautiful valley just mentioned, are separated from each other, by forests, corn-fields, and meadows,—large tracts of ice mingling with the cheerful fruits of cultivation.

Of Norway.

(407.) The finest glaciers in Norway, are those proceeding from the chain of the Justedals Eisberge. They are known to the inhabitants by the name of *Jis-Braeer*, and at times are much dreaded by them on account of the rapidity of their motion, which exceed that of the glaciers of Swisserland.[*] In Krondal, the glaciers are described by Von Buch, as a huge, dazzling, white carpet, fastened on both sides to mighty rocks; and when they have reached the valley, they still continue to push on, like the glaciers of the Rhone. Between the sixtieth and sixty-first degrees of latitude, according to Hagelstam, the perpetual glaciers have a breadth of 4600 feet, or nearly seven-eighths of a mile.[†]

Causes of alteration in altitude of perpetual snows.

(408.) Our limits will not permit us to pursue this chain of inquiry in all its generality, and we must therefore briefly remark, that the variations of temperature occasioned by the ordinary changes of the

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[*] It may be necessary to observe, that we do not confound the phenomenon of the perpetual snows with that of glaciers. The inferior limit of ice is determined by other causes.

[†] These people have an ancient usage of giving a snow-bath to those who, for the first time, pass from the less elevated plains, through the zone on the declivity of the Cordilleras, which may be accidentally covered with snow; the burlesque ceremony agreeing with the baptism which sailors undergo, who for the first time pass the Equator.

[‡] When Humboldt published his Views of the Cordilleras, and his Atlas of New Spain, many regarded with wonder the designs which represented the icy regions of the Cordilleras of Quito and Mexico. Accustomed to the snowy mountains of the Alps and Pyrenees, and to the vicissitudes which they undergo during the successive seasons of the year, they transferred similar ideas to the mountains of the New World, and were surprised to find those glaciers wanting, which in Europe impart so much grandeur and beauty to Alpine scenery. See *Vues de Cordillères*, pl. 5. 10. 16. 25. 35. 42. 51. *et* 61.; and *Atlas de la Nouvelle Espagne*, pl. 16. *et* 17.; and *Atlas Géographique de l'Amérique Méridionalle*, pl. 1.

[§] We must not confound the perpetual snows with the snows which in winter, sometimes, fall in much lower regions. This ephemeral snow, says Humboldt, is never observed under the Equator at 12,467, or 12,795 feet; but in Mexico it is commonly seen at an elevation of 9843 feet. Snow has been seen in the streets of Mexico at 7471 feet, and at 6159 feet, in the City of Valladolid.

[*] An example of their terrific power may not be uninteresting. In the year 1744, the few persons inhabiting the valleys alluded to in the text, complained that they were not able to pay their taxes, because the *Jis-Braeer* had rushed upon their fields, and completely covered them. This statement was not credited, and Surveyors and Excisemen (*Sorenscriver und Foged*) were sent as Commissioners to measure the distance of the middle of *Milvirsdal* from the foot of the nearest glacier, and it was ordered that the same measurement should take place every three years, to ascertain whether or not these glaciers were advancing. Three years after, the same Commissioners went to repeat their measurement, and were not a little astonished to find neither fields nor houses. The *Jis-Braeer* had advanced prodigiously, the inhabitants were gone, and their possessions buried under the ice. (See Thaarup's *Magazin fur Statistik*, 1802.)

In the *Bibliothèque des Sciences et des Arts*, Professor Pictet informs us, that the Glacier des Bossons has lately (1818) advanced fifty feet, much to the dismay of the neighbouring villagers.

[†] There are many mountains in Norwegian Lapland, whose names terminate in *geikna*, and from all of which glaciers proceed. In Lapland, the name *geikna*, or *jackna*, is applied in the same way as the Icelandic word *jockal;* the Norwegian word *jisbræ;* the Tyrolese word *ferner;* and the Swiss word *gletcher*, (glacier.)

seasons, are not the only causes which have a tendency to produce alterations in the elevation of the plane of the perpetual snows. There must be some differences of altitude due to the diurnal changes of temperature, although the present condition of our knowledge will not permit us to estimate their value. The horizontal winds, also, which mingle the temperatures of different zones, contribute sometimes to augment the circumstances of temperature, and at other times to diminish it, in each case exercising some effect on the altitude of the perpetual snows. The enormous beds of clouds likewise, which are found sometimes to exist in the interval between the plains and the limits of constant snow, cannot but be without their effects. The production of caloric, which, says Humboldt, is the effect of the extinction of light, and which diminishes with the density of the superincumbent strata of air, may not, it is true, be appreciable by our instruments; but the masses of vesicular vapour, and the clouds which present distinct and perfect contours, and which in the tropical regions attain an elevation of 3000 toises, become heated to a sensible degree, and emit radiant caloric to great distances. On the other hand, at a less elevation on the Eastern side of the Cordilleras of Mexico, a thick stratum of clouds augments, during several months, the cold of the superior regions, by intercepting the radiant caloric of the plains. Nor must we omit the consideration, that while the directions of the great mountain chains exercise a very important influence on the figure of the plane of perpetual snows, the grouping together of mountains has, in all cases, an effect on its elevation; tending to diminish the altitude, when their summits penetrate above it.

Figure also influenced by inequalities of temperature of Northern and Southern hemispheres.

(409.) We may also add, in again alluding to the figure of the plane of perpetual snows, that on account of the inequalities of temperature which exist in the Northern and Southern hemispheres, some varieties, both in form and elevation, are due on this account. The elevation of the perpetual snows in the parallel of Cape Horn must differ from that of Edinburgh, since the former ranges freely over the Ocean, and the latter is subject to all the vicissitudes of temperature arising from the unequal radiating powers of large portions of the Continents of Europe, Asia, and America. Whatever circumstances, indeed, occasion diversities in the temperatures of the two hemispheres, cannot be without their effects on the altitude of the perpetual snows.

Supposition of Bouguer that temperature of lower limit of snows is constant.

Shown by Humboldt to be erroneous.

(410.) We must now hasten to advert to another most interesting branch of the inquiry. It had long been believed after Bouguer, that the lower limits of the plane of perpetual snow indicated everywhere a temperature corresponding to the freezing point; but Humboldt has shown, in a Memoir read to the French Institute in 1808, and, again, in his Paper on the Inferior Limit of the Perpetual Snows on the Mountains of Himalaya, that such a supposition is contrary to the truth, and that the perpetual snows do not follow an isothermal plane. Their direction, indeed, follows less the traces of the isothermal lines of the planes, than the inflexions of the lines of equal summer. By uniting many good observations, Humboldt found that at the lower limit of perpetual snow, the mean temperature of the air is as recorded in

TABLE XC.

Latitude, or Place of Observation.	Observed Altitude of Plane of Perpetual Snow, above the level of the Sea, in Feet.	Mean Temperature of lower limit of Plane of Perpetual Snow.
At the Equator	15747	34°.70
In the Temperate Zone............	8856	25.34
In the Frigid Zone, in lat. 68°—69°.	3414	21.20

First theoretical attempt to estimate height of this plane.

(411.) The first theoretical attempt to trace the altitude of the plane of the perpetual snows in different latitudes, was also made by Bouguer. Mayer, although occupied with the subject of terrestrial temperature twenty years later, having deduced, as we have before seen, a formula to represent the same, did not venture to trace the gradations of heat in the atmosphere, and to ascend to the frozen regions above. It was sufficient, indeed, for his reputation, that, occupied with the mighty subject of the lunar Tables, he was yet able to marshal the terrestrial temperatures, and develope a law which should approximate in some tolerable degree to that of the geographical parallels. Kirwan, eager to embrace the whole question, ventured to combine the experimental observations of Bouguer with the theoretical deductions of Mayer, and regarded the elevation of the perpetual snows in every latitude, as proportional to the difference of the mean temperature and the constant temperature of the freezing point.

Kirwan combined the observa tions of Bouguer with the deductions of Mayer.

Playfair's formula fo the same object.

(412.) Professor Playfair, also, by means of Mayer's formula of mean temperature, endeavoured to deduce the altitude of the perpetual snows as follows. Since that formula is represented, says he, by

$$T = 58 + 26 \cos 2\,L,$$

and that at the limit of congelation T becomes 32, the equation may assume the form of

$$32 = 58 + 26 \cos 2\,L - \phi,$$

provided we assign to the function ϕ a proper value.

(413.) The value of this function is necessarily dependent on two conditions, the altitude of the point of congelation, and the decrement of altitude due to the change of a single degree of Fahrenheit. It may hence be denoted by $\frac{h}{\Delta}$, if we represent by the numerator of the fraction the first of the elements alluded to, and by the denominator the second. This assumption will, therefore, cause the preceding equation to be transformed into

$$32 = 58 + 26 \cos 2\,L - \frac{h}{\Delta},$$

and from which we obtain

$$h = 26\,\Delta\,(1 + \cos 2\,L),^{*}$$

and which, according to Playfair, will furnish the altitude of perpetual snow for every latitude.

Leslie's vestigati

(414.) Professor Leslie has likewise been led to the consideration of this problem. Having deduced the

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[*] Playfair, in his *Outlines of Natural Philosophy*, assigned to the altitude of perpetual snow at the Equator 15,577 feet, as before given by Kirwan, and hence deduced 294 feet for the value of Δ. In doing this, however, the Professor fell into an error respecting the formula of Mayer, by assigning to the constant coefficient of the double latitude, the value of 27 instead of 26; and hence his equation for the altitude of perpetual frost was

$$h = 7644 + 7938 \cos 2\,L,$$

instead of the more convenient form given to it in the text.

formula before alluded to for the decrement of temperature in the air, he was naturally led to that limit, which gives to it the character of congelation. The Professor communicated to his formula two forms, as we have before seen in the functions represented by (L) and (M), and deduced from either the altitude of the perpetual snows.

(415.) If we adopt that which we have denoted by (M), and represent the temperature at the level of the Ocean by t, we shall obtain the equation

$$25\left(\frac{1}{\theta} - \theta\right) = t.$$

This value of t being known for every latitude, or at least being capable of computation by any formula of temperature, we may regard θ as the unknown element to be determined, and hence obtain, by a simple algebraical reduction,

$$\theta = \sqrt{(1 + .0004\,t^2)} - .02\,t \ldots . \text{(Q)},$$

Relative elasticity of the air at the limit of congelation.

which gives in terms of the temperature at the level of the sea, the relative elasticity of the air at the limit of congelation. The question thus becomes reduced to the ordinary methods of determining barometric altitudes, and on this principle the Professor computed the following Table.

Table XCI.

Leslie's Table for altitude of plane of perpetual snow in every latitude.

Latitude.	Height of Plane of Perpetual Snow in English feet.	Latitude.	Height of Plane of Perpetual Snow in English feet.	Latitude.	Height of Plane of Perpetual Snow in English feet.
0°	15207	31°	11253	62°	3365
1	15203	32	11018	63	3145
2	15189	33	10778	64	2930
3	15167	34	10534	65	2722
4	15135	35	10287	66	2520
5	15095	36	10036	67	2325
6	15047	37	9781	68	2136
7	14989	38	9523	69	1953
8	14923	39	9263	70	1778
9	14848	40	9001	71	1611
10	14764	41	8738	72	1451
11	14672	42	8473	73	1298
12	14571	43	8206	74	1153
13	14463	44	7939	75	1016
14	14345	45	7671	76	887
15	14220	46	7402	77	767
16	14087	47	7133	78	656
17	13947	48	6865	79	552
18	13798	49	6599	80	457
19	13642	50	6334	81	371
20	13478	51	6070	82	294
21	13308	52	5808	83	226
22	13131	53	5548	84	167
23	12946	54	5290	85	117
24	12755	55	5034	86	76
25	12557	56	4782	87	44
26	12354	57	4534	88	20
27	12145	58	4291	89	5
28	11930	59	4052	90	0
29	11710	60	3818		
30	11484	61	3589		

Remarks.

(416.) With respect to the preceding Table it may be remarked, that Professor Leslie has computed the temperatures of the geographical parallels by the formula of Mayer, which not representing exactly the distribution of terrestrial heat, must necessarily have some effect on the computed values for the altitude of the perpetual snows. It proceeds also on the supposition that this plane is one of an isothermal nature, which, we have before remarked, has been proved by Humboldt not to be the case. Hence the differences between the results of the Table, and those recorded from actual observation in Table LXXXIX., are considerable. At the Equator, the formula is only in defect 541 feet, but in the parallel of Mexico the difference, according to one observation, amounts to 1066 feet, and according to another to 1386 feet. With one of the observations made on the Himalaya chain, there is a surprising coincidence between the formula, and the point where the Gauri river emerges from the snow; but at the Nitee Ghaut, the Chárang pass, and the somewhat doubtful results relating to the mountains enclosing the dell of the Táglá river, the differences are of the most surprising kind. With the observations made on the Caucasus, the theory is in defect the enormous quantity of 2213 feet; but with the Pyrenees it is for the first and last time a small quantity in excess. With the Alps it is again considerably minus, and with the estimated range of the perpetual snows above the Carpathian chain, it is in defect upwards of 1900 feet. In Sweden, admitting the observations of Hagelstam to be correct, the difference is still greater; although a somewhat closer approximation is obtained for Folgefonden, in Norway. With the snows on the mountain of Sulitelma, given on the respectable authority of Wahlenberg, the difference amounts to 1512 feet; and at the North Cape, where the last visible traces of the perpetual snows on land are found, the defect still amounts to nearly 800 feet.

Differences between the Table and actual observation.

Graphical illustration of the same.

(417.) These anomalies may, however, be more clearly discerned by means of the graphical illustration denoted by fig. 9, in which the horizontal line E N represents the interval between the Equator and the North Pole, divided so as to correspond with the principal latitudes contained in Table LXXXIX.; and on each vertical line raised at the latitudes referred to, is laid off the altitude of perpetual snow according both to theory and observation. Thus, from E to B denotes the altitude of the perpetual snows at the Equator, as indicated by the Table of Leslie, and from E to G the mean of all the Equatorial observations of Humboldt. A simple extension of the same principle produces the curve of contrary flexure B C D F N, of which the one half is nearly the reverse of the other, for the general range of the perpetual snows according to theory; and the irregular line F G H I K, that which is produced by connecting together the points with which actual observation has furnished us. C is the point where theory so nearly agrees with the measurement found for the Gauri river, and D the solitary example of its being in excess of the actual observations made on the Pyrenees. The towering summit at H is worthy the most attentive consideration. The part of the horizontal line E A refers to the observations of Humboldt made South of the Equator.

(418.) Although the theory is in all cases in defect excepting one solitary instance, it would be unjust to charge upon it the whole amount of the differences that have been found, since errors in the actual observations on the perpetual snows do in all probability exist to

The results of observation cannot in all cases be relied on.

Proof from the decrement of altitude.

some considerable amount. The remarkable circumstance, however, that *all* the differences between theory and observation, excepting one, are of a negative character, is sufficient to awaken a salutary caution respecting its results. That the conclusions of actual observation cannot in all cases be relied on, may be inferred from an examination of the results of Table XC. By computing the decrement of altitude corresponding to a single degree of Fahrenheit's thermometer, for the whole range of elevation from the Earth's surface to the plane of congelation, we shall find the results for the three zones to be of a very anomalous kind. If we adopt for the mean temperatures at the surface, the values recorded in Table XLII., and for the mean temperature of the lower limit of perpetual snow, those contained in Table XC., we shall obtain the following results:

Table XCII.

Latitude, or Place of Observation.	Mean Temperature at the Earth's Surface.	Mean Temperature of lower Limit of Plane of Perpetual Snow.	Decrement of Temperature.	Observed Altitude of Plane of Perpetual Snow above the level of the Sea.	Decrement of Altitude in feet, corresponding to degree of Fahrenheit's Scale.
At the Equator	81°.50	34°.70	46°.80	15748	336
In the Temperate Zone.	57.63	25.34	32.29	8856	274
In the Frigid Zone, in lat. 68°—69°.	29.87	21.20	8.67	3444	396

Causes of the anomalies.

These anomalies may again be attributed to two sources, errors in the altitudes, or in the observed mean temperatures of the plane of perpetual snow in the latitudes referred to; and that it exists with much probability in the latter, may be inferred from the following considerations.

Attempt to compute the mean temperature at the limit of perpetual snow.

(419.) We have before found that the formula represented by (P) denotes, in a convenient manner, the relation between the depression of the thermometer, and the altitude observed; and if we suppose by way of subjecting the three observations in the preceding Table to the same test, that the altitudes are correct, and that the question for consideration is to determine the mean temperature at the altitudes recorded in the same place, let us find from the formula last quoted, that value of n, which represents the depression of temperature due to the elevation. By an ordinary algebraical reduction, this will give

$$n = -83.26 \pm \sqrt{\left(\frac{2h}{3} + 83.26^2\right)},$$

and by adopting as successive values for h, the altitudes recorded in Table XCII., we shall obtain for the values of n, the depressions recorded in the first column of the next Table. By subtracting these from the corresponding mean temperatures at the surface, we shall find in each case the computed mean temperature at the altitude of perpetual snow.

Table XCIII.

Latitude, or Place of Observation.	Computed Values of n.	Computed Mean Temperature at Plane of Perpetual Snow.	Observed Mean Temperature at Plane of Perpetual Snow.	Difference.
At the Equator	48.74	32.76	34.70	+1° 94
In the Temperate Zone	30.04	27.59	25.34	−2.25
In the Frigid Zone in lat. 68°—69°..	12.84	17.03	21.20	+4.17

Inference from it tha it is not an isothermal plane.

Here the errors between the observed and computed values of the mean temperature at the plane of perpetual snow, seem to indicate that considerable anomalies exist in the observations, probably in the temperate and frigid zones. It may also be remarked respecting the formula last employed, that it affords by its application to the principal results contained in Table LXXXIX., a confirmation of Humboldt's remark, that the temperature of the plane of the perpetual snows is not of an isothermal kind. It may likewise be added, that the altitude at which the mean temperature of the freezing point is attained in the great range of the atmosphere, seems according to formula (P) to vanish in about latitude 66° 53′; the great isothermal plane corresponding to 32° of temperature, appearing to meet the Earth's surface in that latitude. This conclusion has been obtained by computing the altitude due to 39° by aid of the formula last quoted, and adopting the mean temperatures recorded in Table XLII.

Probable uncertaint respecting the observ altitudes o the plane perpetual snow.

(420.) There is another uncertainty also respecting the altitudes which have been assigned to the lower limits of the plane of perpetual snow, which must be briefly adverted to. The perpetual snows may be said in a general way to attain their maxima and minima of elevation at the opposite seasons, when the greatest and least temperatures for the year take place at the Earth's surface; and the periods when travellers are most likely to approach them, will not be when they are most broadly developed, but when they are approaching their mean, or, perhaps, their least state; when the warmth of the atmosphere has caused the snowy boundary to rise considerably above the lower limit assigned to it by the minimum temperature of the year. This circumstance may afford room for supposing that the heights assigned to the lower regions of perpetual snow are above what they ought to be; and that hence by applying some correction, which the future progress of Meteorology may disclose, a closer approximation may be found between the results of observation and the deductions of theory; particularly in the temperate and frigid zones, where the discrepancies from this cause may be supposed to be the greatest, in consequence of the greater changes that take place in the altitude of the plane of perpetual frost during the successive seasons of the year.

The whole subject is, as yet, entangled with many difficulties, and will require much laborious research to carry it to perfection. All the anomalies which accompany its progress, must, however, be fairly stated before such desired results can be obtained.*

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* In the following sections (422.) ought to be numbered (421.), and so on.

Isogeothermal lines.

(422.) At the moment this sheet was going through the press, a Memoir on the mean temperature of the air, and of the ground, in some parts of Eastern Russia, reached us, which was read before the Academy of St. Petersburgh in February 1829. M. Kuppfer introduces to our notice in this able paper, a new species of lines which he denominates *Isogeothermal lines*, and which appears likely to lead to some new and interesting results. Kuppfer deduced these lines from the temperatures of springs, and their projections were found to deviate very widely from the isothermal lines.

(423.) Kuppfer determined the positions of his new system of lines as follows. He supposed a relation to exist between the latitude and the temperature of the ground, capable of being represented by the equation

$$a - b \sin^2 l = t,$$

in which l represents the latitude, t the corresponding temperature, and a, b constant quantities necessary to be determined for different meridians. Having determined these coefficients, he found that the observed and calculated temperatures agreed pretty well, excepting for Cumana, Teneriffe, Konigsberg, and Umeo, places upon which local circumstances appear to impress an anomalous character. The meridians assumed by Kuppfer, reckoned from that of Paris, are contained in the following Table, together with the corresponding values of a and b in degrees of Reaumur.

TABLE XCIV.

Meridians.	Values of a.	Values of b.
0°	21°.3	20°.9
20 E.	24.4	25.6
60 E.	22.9	27.5
80 W.	24.0	33.7

By a ready transformation of the preceding formula into the form

$$\cos 2l = 1 - 2\left(\frac{a - t}{b}\right),$$

Kuppfer has been enabled to calculate for each of the preceding meridians, the particular latitudes where any given temperature prevails, and the results of which are contained in the next Table.

TABLE XCV.

Given Temperature.	Corresponding Latitude under Meridian.			
	0°	20° E.	60° E.	80° W.
0°	——	77° 30′	65° 52′	57° 32′
5	62°.12′	60 31	53 47	48 40
10	47.20	48 36	43 14	40 8
15	33.18	37 18	32 25	31 7
20	14.27	24 30	18 57	19 44

By allowing lines to pass through these points of equal temperature, we shall obtain a perfect idea of the positions of some of the isogeothermal lines, which we have represented in fig. 1. pl. ii. by the dotted lines, the isothermal lines being those of a continuous kind.

On Atmospheric Vapour and its Distribution.

Vapour existing in the atmosphere.

(424.) If the phenomena connected with the distribution of heat have disclosed so many interesting results, in no less a degree does the vapour with which the atmosphere is stored. By vapour, we are to understand a very rare, light, expansible body, capable like air of a reduction of volume by external pressure, and also of resisting any force which may tend to compress it. This vapour exists in every climate, and under every variety of temperature; in the frigid atmosphere of the polar zones, as well as in the burning regions of the Equator; nor is there a particle of air uninfluenced by its presence, at least in the lower atmosphere, unless it be relieved from its agency by artificial means. This moisture, extensively as it is diffused, owes its origin to the waters which cover so large a portion of the globe, and which penetrating by a thousand channels, communicate some of their humidity to the earthy soil; and it is to the active agency of heat, that the rising moisture, the result of evaporation, the laws of which we shall hereafter trace, is compelled to distribute itself throughout the different regions of the great aerial volume.

Owes its origin to the waters which cover the globe.

Problem of its distribution a difficult one.

(425.) It will readily be imagined, that to trace in all their generality the laws which regulate the distribution of vapour, throughout the whole extent of the atmosphere, perpetually changing as are all its conditions of density and temperature, must have long been regarded as a capital problem in Meteorology. There is a wide interval, indeed, between the first rude conceptions of the existence of vapour in the air, and those comparatively perfect processes, which our own times have disclosed, respecting the moisture of the aerial columns; and it would be an interesting employment, did our limits permit, to trace up from its feeble beginnings that magnificent chain of discovery, which, connected with the existence and elastic force of vapour, has imparted so splendid a succession of benefits to Man.

Elastic force of vapour.

(426.) The ordinary purposes of Meteorology require only a knowledge of the elastic force of vapour belonging to a comparatively small range of temperature, and the latest inquiries have added but little to the accuracy which Dalton so long ago imparted to them. Very recently, indeed, we have seen the elastic forces pushed up through the extraordinary range of twenty-four atmospheres, by Prony, Arago, Ampère, Gerard, and Dulong; and we cannot sufficiently admire the ingenuity and talent displayed in so laborious and hazardous an inquiry, which we ardently hope will lead to some really practical means of averting the tremendous calamities attendant on explosions by steam.*

Its practical results capable of being represented by a formula.

(427.) We have already given, in p. 333 of our *Essay on* HEAT, the practical results of Dalton and Ure for the elastic forces; and it affords another beautiful example of the power which analysis possesses, of bringing under its dominion a variable force, which the early cultivators of Physics must have placed in almost hopeless obscurity, among the phenomena of Nature incapable of

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* For a full account of these admirable experiments, see *Annales de Chimie, Janvier* 1830, or the *Edinburgh Journal of Science*, July 1830, for a copious abstract of the same.

being investigated by the ardent enterprise of Man. Dalton imagined, however, that he could trace in the columns of his elastic forces, the approximative law of the elasticities of steam increasing nearly in geometrical progression, at the same time that the temperatures augmented arithmetically; and Laplace adopting the same principle, represented the elastic force by an exponential whose exponent could be developed in a parabolic series. To the author of the *Mécanique Céleste*, the two first terms of the resulting series appeared sufficient; but Biot proved the necessity of a third; and while the series thus obtained, represented with considerable accuracy the measures of the elastic forces so long as they were confined within the limits of a single atmosphere, yet when the progress of inquiry ventured on loftier developements of the elastic power, the corrected series of Biot also deviated very widely from observation. At the same time it is worthy of observation, that the French Philosophers, with all the advantages which the formulæ of Prony, Laplace, Biot, Ivory, Roche, Auguste, Tregaskis, Creighton, Southern, Tredgold, and Coriolis could impart, found themselves obliged to limit the application of their own formula to elasticities greater than a single atmosphere.* On the one hand, therefore, we see a series accommodated to the elastic forces *below* the ordinary pressure of the atmosphere, deviating very widely from observation when applied to forces *above* it; and on the other, a formula agreeing with wonderful accuracy up to twenty-four atmospheres—its greatest aberration amounting only to four-tenths of a centesimal degree when estimated in terms of the temperature, yet in smaller pressures than one atmosphere, exhibiting a divergence, to adopt the words of the able Report of Dulong, which increases more and more in proportion as we descend.

Remarks on formulæ in general of this nature.

(428.) It will be sufficient for our purpose, however, to adopt the formula of Biot, and the principle of which he has so fully explained in his *Traité de Physique*, tom. i. p. 273. He there shows, that the general term of the series may be represented by

$$F_t = 30.k^t,$$

Formula of Biot.

where F_t denotes the elastic force corresponding to the temperature $100-t$ according to the Centigrade scale, and k is a constant ratio connecting the elastic force at any temperature with that which precedes it. This ratio, it may be necessary again to remark, is not absolutely constant in the experimental results, but without sensible error may be assumed so, to bring all the observations,—within of course the limits of a single atmosphere, under the control of analysis. The series hence employed by Biot is of the general form

$$\log. F_t = \log. 30 + a t + b t^2 + c t^3,$$

and which he has limited to the third dimension of n, on account of the coefficients of the higher powers of n becoming so minute.

To fix the values of the constants, he has recourse to the absolute measures of the elastic forces at the convenient intervals of 0°, 25°, 50°, and 75° of the Centigrade scale, and thus obtains for the general formula the form of

$$\log. F_t = \log. 30 - 0.0153741265\, t - 0.00006743127\, t^2 + 0.00000003385\, t^3 \ldots. (R).$$

(429.) Thus may the elastic force for any temperature within the limits alluded to be computed, by substituting successively proper values for t. If we take the case of $t = 100°$, belonging to the elastic force of vapour at the temperature of melting ice, we shall obtain

$$F_{100} = 0.19918,$$

and we know the actual observation of Dalton gives for the same

$$F_{100} = 0.200.$$

Considering the difficulty of the inquiry, this must be regarded as a very close approximation.

Conversion of this formula into Fahrenheit's scale

(430.) The formula (R) may be converted into degrees of Fahrenheit's scale by a well-known numerical relation, and which will give to it the form of

$$\log. F_f = \log. 30 + \frac{5}{9} a f + \frac{5^2}{9^2} b f^2 + \frac{5^3}{9^3} c f^3;$$

or by substituting the numerical values of the coefficients, and restoring t to preserve uniformity of notation, we shall have

$$\log. F_t = \log. 30 - 0.0085411814\, t - 0.00002081212\, t^2 + 0.0000000058\, t^3 \ldots (S),$$

in which t denotes degrees of Fahrenheit.

(431.) We regret that our limits will not permit us to pursue this branch of our subject further; but we strongly recommend to the reader's attention the whole of the XIIIth Chapter of the Ist Book of Biot's *Traité de Physique*, or the XIIth Chapter of the IId Book of the same author's *Précis Elémentaire de Physique*, if it be desirable to pursue the subject free from its more scientific details.

Weight of vapour in given volume, at a given density and temperature.

Method of Gay Lussac's.

(432.) The preceding formulæ enable us to discover the elastic force of vapour existing in the atmosphere at any temperature. Let us, therefore, next inquire, what is the absolute weight of vapour contained in a given volume, under given circumstances of density and temperature. To accomplish this object, Gay Lussac employed small globules of glass of a nearly spherical form, as B, B, fig. 2. One of these being accurately weighed, had a portion of water introduced into it, the contained air being expelled, and the narrow neck hermetically sealed. The weight of the ball in this new state, compared with its primitive weight, gave the exact weight of water contained in it. The globule being thus introduced into the glass vessel V V, previously filled with mercury, was surrounded by the vessel M M, containing water; and heat being applied to it, necessarily caused the globule to break, and the resulting vapour to ascend to the summit of V V. Subtracting now the altitude of the mercurial column above the external level, from the ordinary barometric column existing at the same instant, must necessarily give the measure of the elastic force of vapour produced.

(433.) Such is Gay Lussac's accurate method of performing this important experiment, and Biot has illustrated it by some equally beautiful investigations

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* The formula adopted by Arago, Dulong, and their learned associates is $e = (1 + 0.7153\, t)_5$, where e is the elasticity in atmospheres of $0^m.76$, and t the temperature setting out from 100°. It is worthy of remark, that the late learned Dr. Young was the first who represented the elasticities by a certain power of the temperature augmented by a constant number. M. Coriolis adopted 5.355 for the exponent as deduced from Dalton's experiments below 212° of Fahrenheit; and it is remarkable that his formula

$$e = \left(\frac{1 + 0.01878\, t}{2\,878}\right)^{5.355}$$

differs very little from that above given.

Biot's investigations of the same.

of an analytical kind, and which we regret our limits will not permit us fully to follow. He denotes the weight of water in grammes, contained in one of the glass globules by P, and by v the capacity in litres of one of the equal divisions of the receiver, of which N is their number. The resulting volume of vapour might thus be truly represented by $\mathrm{N}\,v$, did not the receiver itself undergo some change in consequence of the altered circumstances of temperature. Representing, therefore, the cubic dilatation of glass by k, the actual volume of vapour will become

$$\mathrm{N}\,v\,(1+100\,k).$$

But this volume, it should be further remarked, is not subject to the whole atmospheric pressure, and if we, therefore, represent the height of the ordinary barometric column by p, and that of the internal mercurial column by h, reducing the whole volume to what it would become under the standard pressure of $0^{\mathrm{m}}.76$, we shall obtain for the volume of a single *gramme* of vapour, at the temperature of the boiling point, the formula

$$\frac{\mathrm{N}\,v\,(1+100\,k)\,(p-h)}{\mathrm{P}.\;0^{\mathrm{m}}.76}\;\ldots\ldots\;(\mathrm{T}).$$

Numerical example.

(434.) This formula Biot illustrates by an appropriate example, the weight of water contained in the globule being $0^{\mathrm{g}}.6$, the number of divisions occupied by the vapour 220, and the capacity of one of them 0.00499316 *litres*. The barometric column also at the same time being $0^{\mathrm{m}}.7555$ at a temperature of 15°, and the mercury within the vessel $0^{\mathrm{m}}.052$ above the external level. By reducing these mercurial columns to the common temperature of zero, and allowing for the dilatation of mercury for each degree of the centesimal scale $\frac{1}{5412}$ of its bulk, we shall finally obtain the following elements,

$$\begin{array}{lll}
\log.\,\mathrm{N} & = 2.3424227 & \\
\log.\,v & = \bar{3}.6983755 & \\
\log.\,(p-h) & = \bar{1}.8465660 & \\
\hline
\log.\,\mathrm{N}\,v\,(p-h) & = \bar{1}.8873642 & \\
\log.\,p.0^{\mathrm{m}}.76 & = \bar{1}.6589649 & \\
\hline
 & \ 0.2283993 & = 1^{\mathrm{l}}.6920 \\
\log.\,100\,k & = \bar{3}.4194865 & \\
\hline
 & \ \bar{3}.6478858 & = \underline{0.0044} \\
 & & \ 1^{\mathrm{l}}.6964
\end{array}
\qquad
\begin{array}{ll}
\log.\,p & = \bar{1}.7781513 \\
\log.\,0^{\mathrm{m}}.76 & = \bar{1}.8608136 \\
\hline
\log.\,p.0^{\mathrm{m}}.76 & \ \bar{1}.6589649
\end{array}$$

from which it appears that a quantity of moisture, equivalent in weight to a *gramme*, is contained in a volume of vapour whose capacity is equal to 1.6964 *litres*, at the temperature of the boiling point, and under an atmospheric pressure of 0.76 *metres* of mercury. We know, moreover, that a *gramme* of water taken at the temperature of the maximum of condensation, occupies precisely a cubic *centimetre*, of which the *litre* contains a thousand; and that hence a cubic *centimetre* of water of this degree of temperature, when reduced into vapour, will fill a space equivalent to 1696.4 cubic *centimetres*. It may also be added, that a *litre* of this vapour, under the pressure above mentioned, and of the temperature of 100°, weighs $\frac{1}{1.6964} = 0.589483$ *grammes*. By reducing these results into English measures, we shall find that a cubic foot of vapour at the temperature of the boiling point, and under an atmospheric pressure of 29.9216 inches, weighs 257.7778 grains.

Weight of a cubic foot of vapour at the boiling point.

Dr. Anderson's method of finding the same at any other temperature.

(435.) But the objects of Meteorology require that a corresponding result should be found for any other temperature. Accordingly Dr. Anderson, in his very able article on HYGROMETRY, published in the *Edinburgh Encyclopedia*, has modified with some advantage, the formula given by Biot for this purpose. If we denote with the author of the Paper alluded to, the weight in *grammes* of a *litre* of vapour at the temperature t by P′, the corresponding elastic force by F_t, the weight in *grammes* of a *litre* of vapour at the boiling point by P; and adopting moreover the principle of Gay Lussac, that vapours so long as they remain in the aeriform state, expand by increase of temperature precisely in the same manner as the permanently elastic fluids, and that they suffer corresponding changes of volume by alterations of pressure, and also that air uniformly expands three-eighths of its bulk from the freezing to the boiling point of the Centigrade scale, we shall obtain by making the requisite substitutions

$$\mathrm{P}' = \frac{1.375\,\mathrm{P}\,\mathrm{F}_t}{0.76\,(1+.00375\,t)},$$

or by substituting for P its value 0.589483 *grammes*, and further reducing,

$$\mathrm{P}' = \frac{1.066499\,\mathrm{F}_t}{1+.00375\,t}.$$

(436.) If again we are desirous of altering the temperatures into degrees of Fahrenheit's scale and the pressure of 0.76 *metres*, or 29.92196 inches, into the pressure of 30 inches, to which that scale of temperature is adapted, we shall obtain after the necessary corrections*

$$\mathrm{P}' = \frac{.0068544\,\mathrm{F}_t}{1+.002086\,(t-32)}\;\ldots\ldots\;(\mathrm{U}),$$

and which, therefore, furnishes the desired weight in known terms of the temperature and elastic force.

Numerical example.

To illustrate this useful formula by a single example, let it be required to determine the weight of a cubic inch of vapour at the temperature of 54°. In this case the value of t being 54°, and F_{54} computed by means of the formula (R) becoming .42779, we shall obtain

$$\mathrm{P}'' = \frac{.0068544 \times .42779}{1.045892} = .00280358 \text{ grains.}$$

And by a similar method may the weight of a cubic inch of moisture be computed for any other temperature.

Dr. Anderson's experiments to determine the accuracy of the formula.

(437.) But it may be useful, however refined and perfect the system of computation, to discover how far the processes of actual experiment will confirm it. Dr. Anderson accordingly made a large volume of saturated air to pass slowly in a small stream through a sufficient quantity of sulphuric acid, or dry muriate of lime, cut off from all communication with the atmosphere; and then observing the increase of weight which these substances acquired in consequence of the air transmitted through them. A complete description of his apparatus may be seen in his Paper

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* An exposition of these important reductions, which we regret we have no room for in the text, may be seen at pages 275 and 276 of Biot's *Traité de Physique*, tom. i.

before quoted, our limits only permitting us to record the results in

TABLE XCVI.

Tabular results.

Volume of Air subjected to Experiment in Cubic Inches.	Temperature in Degrees of Fahrenheit.	Barometric pressure.	Total Quantity of Moisture deposited in Grains.	Grains of Moisture in a Cubic Inch.	
				By Experiment.	By Formula D.
3194	49	29.625	7.550	.0023641	.00235916
10892	54	29.750	28.780	.0026424	.00278021
10814	59	30.000	35.545	.0032867	.00328366
3442	77	29.924	19.574	.0056880	.00568580
11240	83	29.846	75.840	.0067473	.00678455

Remarkable coincidence of the experiments with the formula.

It is gratifying to observe how closely the results of the experiment coincide with the numerical values of the formula, affording at once a strong confirmation of Dalton's researches on the elastic force of vapour, and of the relations which Gay Lussac has established between a volume of dry atmospheric air, and of the quantity of vapour contained in the space which that air occupies.

Union of vapour and atmospheric air.

(438.) Let us next inquire into some of the conditions relating to the union of vapour and atmospheric air. On this subject we may remark, as a general law existing among the dry gases, that if among any number of elastic fluids incapable of being blended together at a given temperature, which separately sustain the pressures $p, p', p'', \ldots$ &c., the same volume V of each be taken, and the whole afterwards reduced into a volume of the same magnitude, we shall find the elastic force P of the united volumes exactly equivalent to the sum of the separate elastic forces; that is

Elastic force of united volume equal to sum of separate elasticities.

$$P = p + p' + p'' \ldots\ldots\ldots$$

and we shall now proceed briefly to show that the same remarkable principle holds good in the union of vapour and atmospheric air.

Gay Lussac's experiment to prove this.

(439.) To demonstrate this problem, Gay Lussac employed a cylindrical glass tube A B fig. 3, divided into parts of equal capacity, and having two stop-cocks at R and R′. A little above the lower cock, a bent tube of glass T T′, of a smaller diameter than the cylinder, communicated with its interior at T. The whole apparatus being perfectly dried, the stop-cock at R′ is opened, and mercury well boiled and dried allowed to fill the cylinder, and to ascend to its proper level in the tube. A globe filled with air brought to a complete state of dryness, is then screwed on at R, and a communication opened between the cylinder and globe, by turning the stop-cocks at *r* and R′. If air of the ordinary density be now introduced into the globe, the mercury will not be depressed in the cylinder A B, and hence the stop-cock at R must be turned, to permit a portion of the quicksilver to descend, and thus allow some of the air to occupy its place. As soon as a sufficient quantity of air has been introduced, its expansion is arrested by turning the stop-cock R; and by turning the other stop-cock at R′ at the same time, the dry air introduced into the cylinder A B is prevented from escaping.

(440.) To introduce the water we are desirous of changing into vapour, another stop-cock R″ is applied, surmounted by a very small metallic vase V, in which the liquid is placed. This cock is not pierced through its centre as stop-cocks ordinarily are, but a small hemispherical depression O below the surface of the interior cone is made to contain a drop of the fluid. If the stop-cock be then turned half a revolution, the watery drop will be brought into the interior of A B, and thus as many drops may be introduced as will produce the desired effects on the volume of air submitted to observation.

(441.) The introduction of the first drop of water must evidently augment the elastic force of the air, and cause the mercury in the tube T T′ to ascend. The effect is sudden but not instantaneous, as it would be if the liquid had been introduced into a vacuum; and by which we perceive that the pressure of the air opposes a resistance to the formation of vapour. If a single drop of the liquid be not sufficient to form all the vapour necessary for the given space and temperature, another may be added to increase the elastic force. After a certain number of drops, however, have been introduced, the addition of any greater quantity will produce no effect, the excess remaining above the surface of the mercury without being reduced into vapour. Biot, with his usual ingenuity, supposes a case in which some drops in excess have been added. By closing the cock R, and denoting the divisions of the tube occupied by the mingled volumes of air and vapour by N′, the elastic force of the two will be found equal to the pressure p of the atmosphere, as at the commencement of the experiment, the gas occupying, however, only N divisions. Its elastic force is thus diminished, and, since in its original condition it was equivalent to p, it must in its new state be represented by $\frac{p\,N}{N'}$. Denoting therefore the elastic force of the vapour by f, at the existing temperature, the measure of the whole elastic force will become

$$f + \frac{p\,N}{N'}.$$

And since this is equal to the pressure p, which is supposed to remain constant, we shall have

$$f + \frac{p\,N}{N'} = p,$$

and from which we have

$$f = p \, . \, \frac{(N' - N)}{N'}.$$

(442.) If now, when the experiment is performed, the actual values of N, N′ and p be observed, the same value for f will be found, as the elastic force of vapour in a vacuum would have afforded at the same temperature. Hence the vapour in its state of union with air preserves its own proper tension, and thus confirms the beautiful law announced, that in the simple mechanical union of vapour with air, each portion of the mixture maintains its own elastic force dependent on the volume it is made to occupy.

In mecha cal union vapour a air, each part mai tains its own elas force.

(443.) The preceding formula gives us the value of the elastic force in functions of the whole atmospheric pressure, and the volumes occupied by the air in its original state, and when united to vapour. By a simple conversion, it may be made subservient, by aid of the

Further plication this principle.

beautiful law just demonstrated, to another important purpose. That law enables us to conclude, that the elastic force of vapour in union with air, exercises its own elastic force, precisely as if no air were present; and hence the absolute value of f, under any circumstances of temperature and pressure, may be calculated by aid of the formula (R). The value of f thus becoming known, it is evident the formula before alluded to will enable us to discover the actual volume which a mixture of vapour and dry air must occupy under the same conditions: for a simple transformation of the formula gives us

Method of determining the actual volume of a mixture of vapour and dry air.

$$N' = \frac{p}{p-f} . N,$$

in which all the elements of the right-hand member are known.

Numerical examples.

(444.) To apply this formula numerically, let it be required to determine the actual increase which a given volume of dry air undergoes, when saturated with vapour at the temperature of 100° of Fahrenheit, and under a pressure of 30 inches of quicksilver. Applying this temperature to the formula (R), we have $f = 1.85241$; and regarding the volume represented by N as unity, we shall obtain

$$N' = \frac{30}{30 - 1.85241} = 1\frac{1}{15} \text{ nearly},$$

and from which it follows, that dry air at the temperature of 100°, when saturated with vapour, is expanded one-fifteenth of its primitive volume.

If we inquire what must be the elastic force of vapour, in order that the dry air with which it is mingled may have its volume doubled under the same pressure of 30 inches, we shall have

$$2 = \frac{30}{30-f},$$

and from which we obtain $f = 15$, a measure of the elastic force corresponding to a temperature of about 180°. If we inquire in what case the volume will be quadrupled, we shall find it at a temperature of about 198°.

If we suppose $p = f$, the value of N′ becomes infinite. For when the elastic force of vapour is equal to the whole pressure of the atmosphere, the air mingled with the vapour no longer bears any pressure, and consequently dilates as it would do in a vacuum, provided always that in proportion as it dilates, the vapour continues to form and extend with it.

Another method of obtaining the same results.

(445.) The law which the preceding apparatus has disclosed, may however be obtained without bringing the mercury to the same level in both its branches. To accomplish this, let us suppose after the reduction of the liquid to vapour, that the mingled volume occupies any number of divisions N′, and that the level of the quicksilver in the lateral tube may exceed its height in the cylinder by the quantity h. In this case, the elastic force of the air dilated into the space N′, will still be expressed by $\frac{pN}{N'}$; and by adding to it the tension f of the vapour, we shall obtain $f + \frac{pN}{N'}$ for the elastic force of the two. This elastic force will not, however, be equal to p as before, but to $p + h$, and hence we shall have

$$f + \frac{pN}{N'} = p + h,$$

and from which

$$N' = \frac{pN}{p - f + h}.$$

This value of N′ will always be greater than N, because $h - f$ must in all cases be a negative quantity. The entire coincidence of this formula with experiment, furnishes a new confirmation of the law whose truth we are endeavouring to demonstrate.

Further modification of the same.

(446.) In the preceding experiments we have supposed as much liquid to have been employed, as is sufficient to furnish all the vapour admissible into the space occupied by the air; but let us now suppose that we only introduce a single drop, and that this quantity is not sufficient to saturate all the space capable of being filled with vapour. After reducing this drop to vapour, let the mingled volume be brought back to the pressure of the atmosphere, by allowing some of the mercury to flow out by the inferior cock. The mixture will then occupy some volume N′, and the mercury in the two branches will thus be reduced to the same level. Let more of the quicksilver be now allowed to run out, so that the mingled volume of vapour and air may occupy any number of divisions N″ greater than N′. The mercury in the smaller branch will thus be found depressed below its level in the cylinder by a quantity h, the elastic force of the mixture being thereby reduced to $p - h$. But if the variation of the corresponding volume during this change of the elastic force be observed, we shall find it to be the same as if it had been perfectly dry gas; and hence we shall obtain generally

$$\frac{N''}{N'} = \frac{p}{p-h},$$

the volumes being inversely as the total elastic forces.

(447.) To discover the kind of variation this result supposes in the elastic force of vapour, let us represent it by f' in its new state of dilatation, its value in the case where the mixture occupied the space N′ having been f. The air contained in the mixture will thus sustain by itself only the pressure $p - f$; and since it occupies at present the space N″, its elastic force will become $(p-f)\frac{N'}{N''}$. By joining this to the unknown elastic force f' exercised by the vapour, the sum must be equivalent to $p - h$, and hence we shall have

$$f' + (p-f)\frac{N'}{N''} = p - h.$$

But experiment gives $\frac{N''}{N'} = \frac{p}{p-h}$;

consequently $\quad p - h = p\frac{N'}{N''},$

or $\quad f' = f\frac{N'}{N''};$

thus confirming the principle of Dalton, that the elastic force of vapour in all cases varies with the volume, precisely as the gases do. And hence we may further deduce also, that the quantity of vapour capable of existing in air, is precisely the same as would be found in a vacuum of equal capacity, under constant circumstances

Quantity of vapour existing in air, the same as in a vacuum of equal capacity.

of temperature and pressure; and that, therefore, the formula (U) which enables us to compute the weight of a cubic inch of vapour, will enable us also with equal accuracy to find the actual weight of moisture in a cubic inch of air, under the same measure of the elastic force.

(448.) In making a practical application of the formula last quoted, the only thing requisite is a convenient mode of determining the elasticity of the vapour already existing in the air, under any proposed circumstances. Mr. Dalton's simple method of filling a tall cylindrical glass jar with cold spring water, and repeating the observation until dew ceases to form on the external surface, first enabled us to obtain this interesting result; but we shall reserve the practical developements of this part of our inquiry, until we come to treat of Daniell's hygrometer.

Actual phenomena observed in union of vapour with the atmosphere.

(449.) Having thus briefly investigated some of the essential conditions of vapour, let us next inquire into a few of the interesting relations it presents, in its union with the great and perpetually changing body of the atmosphere. Every volume of air, from whatever region it may be brought, is more or less charged with vapour. There are indeed two atmospheres which encompass the earth on every side, one of air, and the other of moisture. The union of these by Nature is mechanical only, and each is governed by its own peculiar laws. The atmosphere of air, as we have already seen, possesses permanent elasticity, expanding arithmetically by equal increments of heat, and decreasing in density and temperature as it recedes from the surface. The atmosphere of vapour is also an elastic fluid undergoing condensation by cold, and at the same time evolving caloric, augmenting its force geometrically by equal increments of heat, and permeating the former, and moving in its interstices, like water when in the process of filtration it passes through sand.

Limits set by Nature to aqueous vapour.

Temperature the cause.

(450.) To supply the atmosphere with vapour, the power of evaporation is in almost constant operation, and we might suppose that an agent possessing so great an activity, would in time exhaust the store, boundless as it is, by which that moisture is supplied. But Nature has fixed limits beyond which the aqueous element cannot pass, so as to prevent an undue accumulation of moisture on the one hand, and a state of long continued dryness on the other. These limits are assigned by temperature, and which, whatever may be its apparently capricious changes, is confined, in every climate, within definite bounds. The same heat, therefore, which warms and vivifies the air, and renders the earth an agreeable abode to Man, controls with admirable wisdom the rising moisture.

(451.) This power of the air to acquire moisture is, however, modified by every alteration of temperature, any increase thereof augmenting its store, and every decrease of heat producing a proportional diminution. The greatest and least degrees of heat, whether it be that of a day or a year, must therefore afford some phenomena which influence the condition of atmospheric vapour. In the case of the minimum temperature of a given latitude, and a state of entire saturation of the air, no addition can possibly be made to the vapour it supports, so long as that temperature is maintained. Any augmentation of heat, however, from whatever cause it may proceed, is at once accompanied by an increased power of supporting moisture, and new accessions of vapour may be added to it. The minimum temperature of any period, therefore, whether it be that of a day, a month, or a year, must set a limit to the accession of watery vapour in the air; and thus in every region, the equatorial, the temperate, or the polar, a strong and impassable barrier has been fixed by Nature to the continued accumulation of moisture in the air. And that there is an equally impassable limit on the other hand—that of extreme dryness, also existing, is evident, when we consider, that as every diminution of temperature tends to saturation, so every increment of heat must produce a tendency to dryness; and that as the maximum temperature of the day has itself a limit, and therefore governs this last condition of the atmosphere, so the depression of temperature which immediately follows, by at once increasing the humidity of all the atoms of air which undergo that change, must remove at once the possibility of any long continuance of comparative dryness. There are some occasional anomalies, however, in the extreme conditions of humidity and dryness to which Saussure has briefly alluded in his *Essais sur l'Hygrométrie*, and which sometimes embarrass the inquirer.

Minimum temperatu prevents accumulation of vapour.

Maximum temperatu being fini prevents entire dryness.

(452.) This dependence of moisture on the circumstances of temperature will help us to trace some of the phenomena of its distribution. There is a gradation of heat, as we have before found, from the Equator to the Poles, and also from the surface of the globe upwards, into the loftier regions of the air. Generally speaking, the lowest stratum of the atmosphere, in whatever latitude it is found, must be most abundantly stored with the watery vapour, on account of its being nearest the source from whence that moisture is supplied. If an equality of temperature existed therefore at the surface, a cubic foot of air, in whatever latitude it were taken, would contain, when completely saturated, the same quantity of moisture. But since the temperature diminishes with the latitude, a given volume of air in a state of perfect saturation must contain less and less moisture as we approach the Poles.

Lowest a mospheric stratum most abu dantly stored wi moisture.

Moisture diminish with the latitude.

Moisture diminish as we ascend.

(453.) From a similar cause, the moisture of the atmospheric columns must diminish as we ascend vertically above the Earth; and hence that the whole store of moisture contained in a vertical equatorial column of air, must exceed the quantity found in a polar column of equal diameter and in the same state of perfect saturation. There are many difficulties, indeed, in the way of proving experimentally the decreasing humidity of the air, and one of the most interesting Meteorological observations that can be made in the neighbourhood of a mountain is to determine the exact condition of vapour in the atmospheric strata at different elevations. To resolve the question perfectly, such observations should be made at the same instant at the two extremities of the same vertical line. This, however, is hardly possible to be done, and we must hence select such times and places of observation as are not widely separated from each other. Saussure made many among the Alps with this view, from the valley of Chamouni through several successive elevations, and in a general way found the law to hold good. He met with some instances, however, in which the absolute quantity of vapour was greater in the more elevated regions of the air. Thus by comparing the 75th and 76th Meteorological observation of his *Voyage dans les Alpes*, we shall find that his hygrometer advanced 10°.1 towards humidity, by ascending to a height of 291 toises above his first station, the thermometer of

Anomalies observed by Saussure.

Reaumur at the same time sinking only 1°.6. The second observation, it should be remarked, was made in the midst of the glacier of Hautema, and it is therefore probable the ice and snow with which it was covered supplied this extraordinary humidity. And this opinion is confirmed by another observation which he made on a projecting rock seven toises less elevated, and where he found the humidity 14°.7 less than at the lowest station, agreeing, therefore, with the general principle before advanced. In another observation, however, Saussure is not disposed to attribute all this difference to the ice. Another example is also given by the same indefatigable and accurate observer. In the middle of the glacier of Miage, his hygrometer indicated a humidity of 81°.1, but on the *Col de la Seigne*, 186 toises above the glacier, it indicated 100°, though the decrement of temperature 8°.3 according to Saussure's table, ought to have indicated only a humidity of 89°.9. It sometimes happens, therefore, that vapour is more abundant on the summit of a hill than in the valleys at its base; but as the exceptions are not numerous, and may be explained by the influence of peculiar localities, we may in general conclude, that the absolute quantity of vapour in the air diminishes as we ascend. It should be borne in mind in considering this part of the subject, that the anomalies we have before proved to exist in the temperature of the air at different elevations, must necessarily impart a like irregularity to its humidity.

Vapour sometimes more abundant on the top of a hill than in the valley below.

It is possible to compute the vapour in any atmospheric column, and also in the whole atmosphere

(454.) It would be possible to compute approximatively the actual weight of vapour contained in any of the atmospheric columns, and if necessary the whole quantity of moisture contained in the atmosphere. The experiments of Biot and Arago have determined that the weights of equal volumes of vapour and air at the temperature of the boiling point, and when both are subject to the same pressure of .76 *metres*, are as .589481 to .9454476, or as 5 to 8 nearly; and since both are affected in their bulk in the same manner, by every alteration of temperature and pressure, the same invariable relation may be supposed to be preserved, so long as the vapour retains its elastic form. In some inquiries of this sort it has been assumed, that the mean point of deposition for the globe in general, is about 6° below the average temperature,—though this assumption, from the limited nature of the observations from which it is deduced, cannot be received without caution; and if we adopt in addition another hypothesis, by supposing the same invariable difference of temperature to be maintained, throughout all the atmospheric strata, we may make an approximation to the whole quantity of moisture contained in the atmospheric columns, by means of the formula

$$\frac{5}{8} f \times \frac{407.4}{30},$$

wherein f denotes the elastic force of vapour at a temperature six degrees below the mean temperature of the place of observation, and the numerator 407.4 the height in inches of a column of water equivalent in weight to the mean condition of a corresponding column of the air, and the numerical value of which formula, will give the mean height in inches of a column of water, equal to the whole moisture contained in a column of the atmosphere, standing on the same base. In this way we may compute, that if the atmospheric columns at the Equator were to discharge their whole watery store, the moisture precipitated would cover the surface of the earth only to the small depth of 7½ inches, and in the mean parallel of 45° only about 3⅓ inches. Supposing the whole atmosphere, from a state of absolute dampness, were to discharge its entire watery store, it would only form an uniform sheet of about 4½ inches in depth. To furnish a sufficient supply of rain therefore, as Leslie remarks, it was necessary the air should undergo very frequent changes from dryness to humidity in the course of the year. Supposing the mean quantity of water existing in a state of vapour in an atmospheric column, having a square inch for its base, to amount to about 4 cubic inches, we may infer, that the quantity actually existing in the whole atmosphere amounts to about 12,500 cubic miles.

Depth of water if atmosphere were to discharge its whole watery store.

Such conclusions, however, must be truly regarded as approximations.

(455.) Such results, however, must be truly regarded as approximations, and adopted only to enable us to catch a glimpse of the mysterious phenomena of Nature. We know too little of the humidity of the lower regions of the atmosphere, to speak with certainty of any of the phenomena connected with the higher. We know too little of the phenomena which may be said to be continually within our grasp, to permit us, without the exercise of the greatest caution, to apply them even as humble approximations to those lofty regions of the air, which as yet have defied the aspiring ambition of man. Of this, however, we are certain, that the higher regions of the atmosphere are comparatively drier than those below. Colonel Beaufoy, in his interesting ascent of Mont Blanc, remarks, "that the air itself was thirsty, its extreme dryness," said he, "had robbed my body of its moisture."

Moisture not equally distributed in volumes of same temperature.

Case of Plymouth and Prague.

(456.) The vapour actually existing at any time in the air is far however from being equally distributed in those volumes of it which possess the same degree of temperature. A given volume of it, at the temperature of 50°, in a portion of the atmospheric column reared above Plymouth, may possess a very different degree of humidity from a volume of a like temperature above Prague. The former, from its peculiar locality, may be in a state of high saturation, whereas the other, in the heart of a great continent, and governed by a wind from a different quarter, may be comparatively dry. It is not equality of temperature alone that we must seek for, in applying practically the elements of the problem now under review, but the quantity of moisture coexisting with it. To-day, the air of Moscow may afford a greater proportion of moisture than the warmer atmosphere of Ispahan, and to-morrow the relation may be entirely reversed. Contending winds not only influence the temperature and pressure of the air, but its humidity also; and the peasant of our own country is familiarized with their different effects. One breeze may bring to him gentle and fertilizing showers, and another may burn up the produce of his farm.

Moscow and Ispahan.

Different quantities of moisture in same atmospheric column.

(457.) But we need not go to the atmospheric columns of different Countries to seek for diversities of moisture, since like anomalies are sometimes to be found in different strata of the same column. Saussure remarked that his hygrometer, near the surface of the earth, often proved the air to be removed 30 or 40 degrees from extreme saturation, when the presence of clouds in the upper sky demonstrated the entire humidity of that region. That eminent observer often remarked this phenomenon when he ascended a mountain whose summit was enveloped in a cloud. On the other hand he as frequently observed, that when mists covered

Effects of clouds.

Of mists.

the plains, and a bright sun gilded the summits of his noble mountains, the limit of extreme humidity was to be found below, and air far removed from saturation above. Bands of clouds were sometimes also found to swim between masses of air necessarily less humid than the clouds themselves. Of the effects of clouds in augmenting the humidity of the atmosphere, he has one conclusive observation. When on the summit of Mont Brevan, 1306 toises above the sea, his hygrometer, at a moment when the sky was free from clouds, indicated a degree of moisture corresponding to 86°.8; but when the summit of the mountain was soon after enveloped in a cloud, the humidity increased to 94°.6.

Actual example of humidity of a cloud.

Elastic force of vapour does not diminish uniformly as we ascend.

(458.) Mr. Daniell has also deduced, both from theory and the actual experiments of Captain Sabine, that the elasticity of vapour does not diminish in an uniform manner, according to the decrease of temperature and density of the air, but the dew-point remains stationary to a great height, and then suddenly falls to a large amount. At Sierra Leone, the dew-point at the level of the sea was found to be 70°, and at the same hour upon the summit of the Sugar Loaf mountain, 2520 feet above, it was found exactly the same. At Jamaica also, by the sea-side, the temperature of the air was 80°, and the point of deposition 73°; while on the mountains, at an elevation of 4080 feet, they were both 68°.5. At a station not 500 feet higher, by an experiment twice repeated, the point of deposition was found to be 49°, and the temperature of the air 65°. Mr. Green the aeronaut also found, when ascending from Portsea, that at an elevation of 9890 feet, the dew-point was 64°, the same as at the surface of the earth; but at 11,060 feet it fell to 32°, making a difference of thirty-two degrees in a little more than 1100 feet; affording a decisive example, as Mr. Daniell observes, of an immense bed of vapour rising in its circumambient medium, unaffected by decrease of density or temperature, till checked by its point of precipitation; and also of an incumbent bed of not much more than one-third the density, regulated, no doubt, as the last, by its own point of deposition in loftier regions. Such phenomena afford strong experimental evidence of the mechanical mixture of the aqueous particles in the atmosphere, and admit of no explanation by any law analogous to that of chemical solution.

Examples.

Proofs which they afford of the mechanical mixture of vapour with air.

Want of practical observations.

(459.) We have before lamented the want of correct observations to assist us in our inquiries respecting temperature; and with equal reason may we deplore the absence of accurate and extended results to illustrate the much more varied conditions of humidity. The thermometer has existed for a long period in an accurate form to assist the Philosopher in every inquiry respecting heat, but an hygrometer which should disclose the *absolute* circumstances of atmospheric vapour has been but recently known. Mr. Daniell's beautiful instrument, and which we shall hereafter describe, enables us to trace with the greatest exactness all the conditions of humidity; but the limited observations hitherto made with it, afford but little information respecting that general distribution of vapour, which we are here desirous of tracing. As the observations made by the thermometer have enabled us to trace the numberless aberrations of temperature, and to distribute them in isothermal lines, so, had this hygrometer existed a century ago and been diligently applied, might we have traced some of the singular mutations of the great ocean of vapour which surrounds us, and have deduced perhaps from the mean results lines of equal humidity.

Lines of equal humidity.

Desiderat respecting the humidity of the atmosphe

(460.) It is a great practical problem therefore now opened to the ardent enterprise of Meteorologists, to discover, if possible—and what will not united labour and Philosophical enterprise effect,—some accurate relations respecting the distribution of moisture; to trace some of the varying conditions of humidity, which, for ever working in the great aerial volume around, is one of the main springs of the uncertain motions of the air, and of those changes of the weather, which are not only so much blended with our personal health and comfort, but with all the important processes of agriculture. At the present moment we can do little more than say, that of this wide-spreading ocean of vapour, we can merely estimate its elastic force and quantity at a given time, and in a general way trace an analogy between the course of its changes, and the progress of the mean temperature of the year. We know not where to look for the data which will enable us to contrast Philosophically the humidity of different climates, to measure the influence of mountains and valleys in modifying the conditions of vapour, the sea which exercises its own peculiar laws, and the islands and continents which diversify in so great a degree all the phenomena of humidity.

What we present know respecting humidity of the atmosphere

Not able contrast humidity different climates.

Connecti of the humidity of th atmosphe with lan and sea winds.

(461.) It is a useful problem, unquestionably, to determine the mean temperature of a place; but it is a problem of no less interest to discover its mean humidity. In Great Britain the winds which transport the vapour may be divided generally into two classes: the land winds blowing from off the great continent of Europe, and which comprise the North-East, East, and South-East; and the sea winds passing over the waters which surround us on every side, the North, North-West, West, South-West and South. In the former we might expect to find the course of the mean temperature exactly followed, because the sources which supply the vapour must be comparatively shallow streams and reservoirs of water, whose temperature readily adapts itself to that of the surrounding air; but in the unfathomable depths of the great ocean which affords humidity to the latter, the peculiar law by which the density of water is governed, must at particular periods maintain a temperature above that of the declining season, whilst at others, the increasing heat of the latter must outstrip the progress of the former.

(462.) Here then is a single problem, the elements of which must vary with every locality. Swisserland, surrounded on all sides by mountains, must present different phenomena from Great Britain, surrounded on all sides by the sea. For London, Mr. Daniell has found that the vapour of the land winds declines in force from September to January, when it reaches its minimum, and from that lowest point gradually rises to a maximum in August, thus following the course of the mean temperature of the air. In the sea winds, however, the vapour declines from September to November, when an equality appears nearly to take place in the humidity of the two winds; but in December, the vapour from the land descends below that of the sea, and the same difference continues to January. In February the former rises two degrees, and the latter remains stationary. A difference of four degrees continues through March, and which is diminished to three degrees in April and May. In June they again attain their former equality, because the temperature corresponding to the maximum density, cannot be lowered

Mr. Da niell's servati on hun of the peculi winds London till the whole mass of waters has passed this limit; and in the deep seas this must necessarily be a process of some duration. The shallow waters on the contrary, over which the land winds pass, must soon acquire the temperature of the ambient air, and continue to decline with it in heat. Upon the return of Spring a contrary effect takes place. The Ocean must again repass the temperature corresponding to the maximum density, before the waters can again obtain the higher temperature of the surrounding air. A necessary consequence of such an arrangement of things must be, an increase of humidity in December and January, and a rapid diminution in the four succeeding months, a phenomenon found to agree with actual observation. Such is the contrast exhibited by the prevailing land and sea winds peculiar to London. How very different would be the phenomena of the winds peculiar to Moscow!

The numerical results from which Mr. Daniell has deduced these interesting conclusions are exhibited in the following Table.

Table XCVII.

Of the Difference of the Dew Point in the Land and Sea Winds.

Months.	Land Winds. N.E. E. S.E.	Sea Winds. N. N.W.W. S.W. S.
September	53°	53°
October	45	46
November	41	42
December	31	37
January	29	35
February	31	35
March	34	38
April	45	42
May	47	44
June	54	54
July	52	55
August	56	57

Influence of the Polar ice on the humidity of London.

(463.) The peculiar locality of Great Britain may also be supposed in another way to modify the production of vapour, by its having to the North, at one season of the year, enormous masses of ice, which during their formation evolve caloric, and, in the process of liquefaction, occasion its absorption. Dividing the winds into two classes, Northerly and Southerly, Mr. Daniell has been enabled to trace their effects on the moisture of the air, as given in the succeeding Table.

Table XCVIII.

Of the Effect of the Ice in the North Seas upon the Dew Point.

Months.	Southerly. S.W. S. S.E.	Northerly. N.E. N. N.W.
September	58°	48°
October	51	41
November	47	37
December	42	32
January	38	31
February	36	31
March	42	32
April	47	40
May	51	41
June	58	50
July	58	50
August	60	54

By attending to the results of this Table we may first observe a constant difference of the temperature of the Dew point to prevail from September to December, in the two classes of winds; but the Dew point belonging to the Northerly winds, having reached that of the freezing point in the last-mentioned month, continues nearly uniformly to preserve the same temperature, during the succeeding months of January, February, and March, while in the Southerly winds, the declension continues through January and February only. In March the Southerly winds impart an increment of six degrees, but the increase of the Dew point of the Northerly winds does not take place till April, when the addition it receives, amounts to eight degrees, at which point it continues with little variation through the whole month of May, the absorption of heat during the process of thawing, preventing that accession of temperature which is due to the returning influence of the Sun. As soon as this operation, however, has ceased, the vapour rapidly regains its former relative degree of force, imparting considerable increments to both classes of winds in June and July, until their maximum conditions are obtained in August, and are followed of course by a decline of both in September.

Mean results of distribution of aqueous vapour in successive seasons of the year for London.

(464.) We must now take a hasty glance at the few imperfect results we are able to offer respecting the distribution of aqueous vapour during the successive seasons of the year, still, of necessity, limiting our inquiries to the locality of London.

Beginning with January, the time at which the minimum temperature prevails, Mr Daniell found, from a mean of three years' observations, and a triple observation each day, the mean elastic force of the vaporous atmosphere to be also at its lowest point, and represented by 0.234 inches of quicksilver, the mean temperature being at the same time 36°.1. As the mean temperature advances through the month of February to 38°, the force of vapour increases feebly to 0.239 inches. With the month of March, however, the mean temperature is augmented nearly six degrees, the elastic force of the vapour advancing at the same time to .272 inches. In April the mean temperature of the air rises to 49°.9, and the elastic force of vapour to .322 inches. In May, the atmospheric temperature still outstrips the advance of vapour, the former amounting to 54°, and the latter to .354 inches, the air having then nearly attained its greatest state of dryness. During the month of June the advance of the mean temperature and humidity are nearly uniform, the former being 58°.7, and the force of vapour .410 inches. Through July, the moisture augments with rather greater rapidity than the temperature, the elastic force being .468 inches, and the mean temperature 61°. In August, these phenomena continue nearly the same, the force of vapour being .481 inches, and the mean temperature 61°.6. During September, the reduction of temperature is first felt sensibly, its mean sinking to 57°.8, the vapour at the same time declining to .432 inches. In October, the mean temperature falls to 48°.9, and the elastic force to .336. During the dark and dreary month of November, the atmosphere becomes nearly saturated with moisture, the mean temperature falling to 42°.9, and the mean elasticity of vapour to .286 inches. December exhibits nearly the same characteristics, the mean temperature being 39°.3, and the elastic force of vapour .261 inches.

(465.) The preceding abstract forms, as we have

Aberrations from the mean results.

stated, the mean results for the respective months; but what, it may be asked, are the aberrations exhibited during each, by particular winds? a cause which is for ever modifying all the phenomena of vapour. The following maximum and minimum temperatures of the Dew point peculiar to each month, have been deduced by Mr. Daniell.

TABLE XCIX.

Months.	Maximum Temperature of Dew Point.	Wind.	Minimum Temperature of Dew Point.	Wind.
January .	42°.5	S. W.	23°.5	E.
February .	39.5	S. W.	29.0	N. E.
March ...	47.0	S.	31.0	N. E.
April	49.0	S. E.	40.0	N.
May	54.0	S.	40.5	N. E.
June.....	62.0	S.	49.5	N. or N. E.
July	59.0	S. W.	49.0	N. E.
August...	63.0	S.	53.0	N. E. or N. W.
September	61.0	S.	45.0	N.
October ..	53.5	S.	38.5	N.
November	48.0	S.	35.5	N. W.
December.	45.5	S.	27.5	E.

Monthly results.

Relation of vapour and mean temperature of the year.

(466.) Mr. Daniell has graphically illustrated some of his interesting results. In fig. 4, we have an example of the monthly progress of the mean temperature and mean Dew point. The full line exhibits the progress of the former, and the dotted line that of the latter, the degree of dryness belonging to each period being accurately represented by the interval between the two curves. We may hence perceive how closely the constituent temperature of the vapour follows the mean temperature of the air, by the general resemblance of the two curves; and also how clearly they exhibit the comparative dryness of the Spring and summer months, and the dampness of the autumn and winter.

Diurnal results.

Relation of vapour and minimum temperature.

(467.) In fig. 5, which has also been derived from Mr. Daniell, this general accordance of the mean temperature and of the Dew point is rendered still more evident, by the variations of the daily mean for forty-five days in September and October 1819. And to exhibit the analysis of this relation more completely, fig. 6 is given from the same respectable source, deduced from observations made four times each day, together with the daily maxima and minima. An accurate inspection of this last figure most clearly demonstrates that there is but little relation between the maximum temperature and the elastic force of the vapour, and that the vapour appears to be governed principally by the daily minima, thus practically confirming the principle before advanced on the authority of Dr. Anderson.

(468.) That the quantity of vapour existing in the atmosphere near the level of the sea, must follow the course of the mean temperature during the successive seasons of the year, may also be inferred from the consideration, that the existence and quantity of vapour in the air, must be governed entirely by its temperature, and that the rate of evaporation is dependent on the same cause. Hence it follows, that whatever influences the temperature, must at the same time affect the quantity of vapour existing in the air; and as through the changes of the year, the mean temperature rises and falls, in a general way it is found that the quantity of vapour in the air must rise and fall with it. In very short intervals, it is true that aberrations may present themselves apparently in opposition to the Principle which has been advanced, but on a great scale it may be clearly and satisfactorily traced.

Changes of pressure of air opposite to pressure of vapour.

(469.) It is also worthy of observation, that if the pressure of the aqueous vapour be separated from that of the aerial, it will in general be found to exhibit changes directly opposed to the latter. This can be best discovered in the daily fluctuations of the atmosphere; and, in the graphical projections which may be made to illustrate the two, it will be found that the undulations of the curve representing the pressure of the whole atmosphere, are directly opposed to those of the vapour, a rise in the line of vapour being generally accompanied by a fall in the barometric curve, and *vice versâ*.

Attempts t connect the indications of an instru ment with the quantity of vapour found in the air.

(470.) Another method, however, of a very different kind has been adopted by some Philosophers to discover the circumstances of atmospheric humidity. Instead of regarding the elastic force of vapour, its density, and the law of its dilatation, as so many independent elements to be found, and by an operation connected with some functions of the density and temperature, to discover thence all the conditions of moisture at any given time or place, an attempt has been made to connect the indications of an instrument with the tensions of vapour at different temperatures, and thence to deduce all the hygrometric conditions of the air. Saussure first endeavoured to establish a relation of this kind, but it is to the later labours of Gay Lussac that we would now especially refer. Of the two methods we certainly prefer the former, but we owe to our readers an explicit account of the latter.

Gay Lussa employed Saussure's hygromete for this pur pose.

Results ob tained by him at the temperature of ten centesima degrees.

(471.) To accomplish this object, the celebrated Chemist alluded to procured one of Saussure's Hygrometers, as accurately and delicately made as the circumstances of its construction would permit; and placed it in a receiver containing some water, or a solution of a Salt of a known Specific Gravity, and then observed the degree which the instrument marked, under the circumstances of saturation in which it was placed. This experiment was repeated under the same conditions of temperature, for different tensions of vapour between the limits of perfect dryness and absolute saturation. In this way the results of the next Table were obtained for the temperature of 10° of the Centigrade scale, the tensions of the liquids employed being expressed in parts of the tension of pure water, which was represented by 100.

TABLE C.

Solutions.	Specific Gravity at the Temperature of 10° of the Centesimal Scale.	Tension of the Solution at 10° of the Centesimal Scale, that of Water being represented by 100.	Degrees of the Hygrometer corresponding to the different Tensions.
Water	1000	100.0	100.0
Muriate of Soda.	1096	90.6	97.7
Ditto.	1163	82.3	92.2
Ditto.	1205	75.9	87.4
Muriate of Lime.	1274	66.0	82.0
Ditto.	1343	50.5	71.0
Ditto.	1397	37.6	61.3
Sulphuric Acid.	1493	18.1	33.1
Ditto.	1541	12.2	25.3
Ditto.	1702	2.4	6.1
Ditto.	1848	0.0	0.0

Graphic illustration of the same.

(472.) The relation of these results may, however, be more clearly explained by means of a graphic illustration. For this purpose their author had recourse to a curve whose coordinates x and y should respectively denote the tensions and hygrometric degrees observed. At the origin of this curve, the values of x and y were to be severally zero, because that point of the hygrometric scale answered to extreme dryness; and at the other extremity of the scale, the same coordinates were to be respectively equivalent to 100, because 100 degrees of the hygrometer corresponded to complete saturation. Between these limits, the experimental results obtained by Gay Lussac afforded many intermediate points for the curve, and which upon investigation he found to be a hyperbola, having its concavity turned towards the line represented by x, and its axis inclined in an angle of 45°, forming the diagonal of a square whose base was the abscissa $x = 100$, and altitude the ordinate 100 corresponding to $x = 0$; the hyperbola being thus symmetrically disposed with respect to the two sides of the square. This result we may venture to say could have scarcely been anticipated *à priori*.

Curve whose coordinates are the tensions and hygrometric degrees a hyperbola.

Analytical investigation of the same.

(473.) To investigate these conditions analytically, it will be necessary to transform the original coordinates x and y, into others x' and y', likewise rectangular, but related to the same axis of the hyperbola, and having their origin in some assumed point of it. This new line of abscissæ must thus form an angle of $-45°$ with the former abscissæ; and by naming (x) and (y) as the primitive coordinates of that line, we shall obtain

$$x = (x) + \frac{1}{\sqrt{2}}(y' + x'),$$

and

$$y = (y) + \frac{1}{\sqrt{2}}(y' - x').$$

These equations, however, may be simplified, by representing by unity the abscissa x corresponding to the tension 100, and which assumption will enable us to obtain the expression

$$y = 1 - x;$$

and since the primitive ordinates (x) and (y) are similarly related, we shall in like manner obtain

$$(y) = 1 - (x).$$

The general equations above given will thus assume the forms of

$$x = (x) + \frac{1}{\sqrt{2}}(y' + x'),$$

and

$$y = 1 - (x) + \frac{1}{\sqrt{2}}(y' - x'),$$

and which by addition will further give

$$y' = \frac{x + y - 1}{\sqrt{2}}.$$

Numerical example.

(474.) If we select, by way of application, the third result given in the Table for the muriate of lime, and the density of which is 1397, we shall have according to the limitation before assigned to the abscissæ

$$x = 0.376,$$

and

$$y = 0.613,$$

and which being substituted in the last equation will give

$$y' = \frac{-0.011}{\sqrt{2}} = -0.00777818;$$

and this being so minute a quantity, the point in the curve to which it refers, may, without any sensible error, be regarded as the vertex of the hyperbola. But to avoid any unnecessary error, the origin of the abscissa x' may be assumed at that point of the axis, where the latter is intersected by y'; and then the value of (x) may be found by adding 0.376 to the projection of y' on the axis of x, or in other words, to $y' \cos x$, or 0.0054996, and which will hence give

$$(x) = 0.3814996,$$

thus determining completely the relations of the two systems of coordinates. Hence we shall obtain the two equations

$$x' = (x - 0.3815)\sqrt{2} - y',$$

and

$$y' = \frac{x + y - 1}{\sqrt{2}}.$$

When x and y are both given, we can readily obtain the value of y' as before illustrated; and this being substituted in the former of these last equations, will give the value of x'. According to this method the following Table has been computed.

TABLE CI.

Primitive Coordinates.		New Coordinates.	
x	y	x'	y'
0.000	0.000	+0.167384	−0.707107
0.122	0.253	+0.074953	−0.441942
0.376	0.613	0.000000	−0.007778

Equation of the hyperbola.

(475.) These elements are sufficient to determine the nature of the hyperbola. For since its axis coincides with the line on which the abscissæ x' are reckoned, its equation must be necessarily of the form

$$y'^2 = a + 2bx' + cx'^2,$$

the values of the constant coefficients being determined by the respective values of x' and y' in the Table. Thus we shall obtain

$$a = 0.0000605,$$
$$b = 1.149338,$$

and

$$c = 4.086830.$$

If, moreover, we assume $(x - 0.3815)\sqrt{2} = s$, we shall further have $y' = s - x'$, and this being substituted in the equation for the hyperbola, will give

$$(s - x')^2 = a + 2bx' + cx'^2,$$

the resolution of which quadratic gives

$$x' = -\frac{(s + b) + \sqrt{((s + b)^2 + (s^2 - a)(c - 1))}}{c - 1},$$

and hence

$$y' = \frac{sc + b - \sqrt{((s + b)^2 + (s^2 - a)(c - 1))}}{c - 1}.$$

The value of y' thus found, being substituted in the equation

$$y = 1 - x + y'\sqrt{2},$$

Formula for computing the hygrometric degrees in terms of the observed tensions.

will determine the function y in terms of x, and thus enable us to compute the hygrometric degrees in terms of the observed tensions; and Biot, at page 533 of the Ist volume of his *Traité de Physique*, has furnished us with a table of all the necessary results from zero to one hundred degrees of Saussure's scale; and a simple inspection of which will at once afford the means of discovering the relation between the degrees of the hygrometer, and the density of the vapour to which the instrument is exposed. If we multiply also the weight in grains of the moisture in a cubic inch of vapour of the given temperature, by the relative tension corresponding to the observed degrees of the hygrometer, we shall obtain the weight of moisture in grains in a cubic inch of air.

Inquiry if the relation of the tensions and hygrometric degrees is general for all temperatures.

(476.) Limited as these computations have been to the temperature of ten centesimal degrees, it becomes important to inquire whether the relations of the tensions and the hygrometric degrees will remain the same at any other temperature. We might, indeed, at first view, suppose, that when the index of the instrument marked a hundred degrees, under circumstances of entire saturation at any given temperature, that at any other degree of heat, and with as complete a saturation as that temperature will permit, the same indication of the instrument would take place. There is reason, however, for supposing that such a desirable condition will not hold good;—that the affinity of the hair for moisture is somewhat modified by temperature, and that thus the relation of the coordinates of the hyperbola must change. Ingenious and interesting therefore as the method is by which these results for the observed temperature have been found, we cannot with perfect confidence extend them to other temperatures; nor must we omit stating explicitly, that the *relative* results which this and other instruments of a like kind exhibit, however convenient they may be for some Meteorological purposes where a rigid and Philosophical accuracy is not required, are by no means to be compared with those *absolute* results, which an attention to the conditions of temperature and barometrical pressure afford. We must not, however, enter here on a discussion of the merits of Hygrometers, but hasten to the subject of evaporation.

Absolute results to be preferred to relative.

Evaporation.

Evaporation.

(477.) We come now to the consideration of that process of Nature, which by its incessant activity affords all the moisture with which the atmosphere is stored, and which quickened by every wind, and augmented by every increment of heat, is continually exerting some effort to return the humidity which the rain and the dew may discharge on the Earth.

Remarks connected with its History.

(478.) The History of this department of Physics is replete with interest. Great names have been connected with it, and the subject has been a difficult one to pursue. Men at one time thought that an essential difference existed between the vapour produced above and below the boiling point. In the lower temperatures, it was imagined that moisture was devoid of elasticity, and hence arose the famous theory of Halley that water is dissolved by air. Deluc and Saussure achieved a great step, therefore, when they proved that vapour of every temperature had elasticity; and a step hardly less important was accomplished by Saussure and Pictet, when they found evaporation to be accelerated *in vacuo*. A true and perfect theory of spontaneous evaporation was, however, reserved for **Dalton**, a name which seems to rise in importance the further we proceed.

Water w assume t form of vapour a all tempe atures.

(479.) It is a law of Nature, now absolutely demonstrated, that water has a tendency to assume the elastic form of vapour at all temperatures however low. Our ordinary experience, indeed, must tend to convince us of its truth, since the product of every shower soon disappears, and ice and snow are wasted by its irresistible power. The sea too performs its part on a grand and magnificent scale. Millions of tons are raised by its agency every day, and a copious evaporation is absolutely necessary to diminish the enormous accessions of water which the Ocean continually receives. The silent and unobserved process by which water is compelled to evaporate spontaneously at all temperatures, is one of the most interesting and important in the whole economy of Nature. The growth of plants and the existence of every living creature depends upon it.

No mat rials for compari the evap ration o differen climates Anomal

(480.) We have no materials for tracing experimentally the phenomena of evaporation in different climates, though we know from its general relations to heat, that it must exist in its greatest power in the Equatorial regions, and, diminishing in some way with the latitude, will be found in a state of even comparative activity in the icy regions of the Pole. Anomalies, however, and some of a very remarkable kind, present themselves in these widely extended regions, and the same terrestrial parallel possesses them in different degrees. The Mediterranean Sea, surrounded on all sides by land, is more heated than the Ocean in the same degree of latitude, and the winds which blow over it, being thus rendered drier, promote a more copious evaporation than in the Atlantic itself. The annual evaporation at Whydah has been estimated at 64 inches, but when the Harmattan blows that rate is augmented to 133 inches. With such anomalies therefore, and with so few facts to guide us, it is no wonder that difficulties arise on all sides when we endeavour to trace the laws, which, in spite of such great aberrations, undoubtedly govern evaporation in every climate.

Remar concer the eva ration atom o water placed the ce of a s rical m meter.

(481.) Before we proceed to consider the experimental laws which the sagacity of the Philosopher has already determined, let us attend for a moment to the phenomena disclosed by the evaporation of an atom of water when placed in the centre of a spherical manometer, surrounded on all sides with an infinity of concentric spherical beds of dry air. In such a condition of things, the process of evaporation must at once commence on all sides of the spherical drop, and the stratum of air in immediate contact with it, will be the first to become saturated with vapour. The vapour thus imparted to the first atmospheric stratum, from its occupying a station in immediate contact with another bed of dry air, will at once exert its elastic power and expand according to the mechanical resistance which this second bed permits. In this way, we may imagine moisture to be transmitted from one successive bed to another, but in continually diminishing quantities as the beds are further removed from the centre; and a moment of time may be conceived when the beds of the manometer most removed from the origin of the vapour, are just beginning to receive the first impressions of humidity, whilst the central beds have already acquired all that the circumstances of their temperature will permit. As each particle of vapour, however, tends continually to diffuse itself in the space on which it immediately borders, if the quantity of vapour be less than the circumstances of temperature permit, the process of evaporation cannot cease on the surface of the watery atom at the centre, nor can the humidity imparted from one successive stratum to the other be checked, until the whole mass of air which occupies the manometer, shall have acquired all the moisture which the given temperature demands.

Application of the atmosphere itself.

(482.) In applying to the atmosphere the Principles of this illustration, we shall be able to trace the general Principles of evaporation. The air confined within the manometer may be supposed to be enlarged into the magnificent volume surrounding the Earth, and the surface of water exposed to its free action in a vessel of any kind, may be assimilated to the atom of water placed at its centre. If we suppose as a first example the whole extent of our atmosphere to be of one uniform temperature, and that there already exists in it all the vapour which this temperature will support, no evaporation can possibly take place from the water that is exposed; but if with this condition of uniform temperature, the vapour already existing in the air be below the maximum which that temperature admits, the evaporating process must at once commence, and the water in the vessel being only as a point when compared with the whole extent of the air to which it is exposed, will at length be entirely dispersed, and that without sensibly increasing the tension of the vapour already existing in it. This vapour, indeed, can have no other effect than to modify the rate of evaporation, and which will be more and more rapid as the air happens to be nearer a state of complete dryness.

(483.) To simplify the subject, we have supposed the temperature uniform throughout the whole extent of the atmosphere, but such a supposition, as we have before seen, is far from representing its actual condition. Inequalities of temperature exist on every side, and the unequal distribution of heat will at once produce its effect on the water exposed for evaporation. A volume of air in one position may thus gain a larger share of humidity than another. Inequality of temperature may exist, or one of the volumes may already possess a greater proportion of vapour than the other. The rate of evaporation will thus be changed, and every variety of it may hence be supposed to exist on a surface so infinitely diversified as that of our Earth.

Law of evaporation proportional to the area of the humid surface.

(484.) It may be announced as a general proposition, that the rate of evaporation is always proportional to the area of the humid surface, and, in air entirely quiescent, it appears, that position exerts but very little influence. A sheet of paper, observes Leslie, applied to a plate of glass in a close room, will lose its moisture just at the same rate, whether it be held vertically or horizontally, and whether it occupies the upper or under side of the plate. The quantity evaporated from a wet ball will be the same as from an equal plane, or by a well-known property of the sphere, as from a circle twice its diameter.

Remarks concerning water evaporating from vessels of different magnitudes and forms.

From water also contained in vessels of any magnitude and form, and of equal or unequal depths, the rates of evaporation, at least in tranquil states of the atmosphere, and when the circumstances of temperature and situation are the same, will be proportional to the magnitude of the watery surface exposed to the action of the air. Muschenbroëk, indeed, asserts, that the deepest vessel is always found, after a certain interval of time, to have suffered the greatest waste, and that the quantities evaporated are as the cube roots of the heights, their orifices and other circumstances being the same. He remarks, however, that when the experiment was performed in a room, no sensible difference was perceptible.

Different opinions.

Leslie also asserts, that the deepest vessel evaporates most copiously, and grounds his opinion on the Principle, that the shallowest vessel receives more readily than the other, the chilling impressions which accompany evaporation; and that the larger mass being thus kept invariably warmer than the other, must, as evaporation is always accelerated by heat, afford a more copious supply of moisture than the other. Lambert, however, like Leslie, a refined experimenter as well as a great Mathematician, found from observations continued through several months, in different temperatures and under many varying circumstances of situation, that in vessels of very unequal dimensions both in diameter and altitude, all other things being the same, the quantity evaporated was always proportional to the surface of the water in immediate contact with the air, and that no other exception appeared to the law than the errors necessarily arising from observation. Saussure, it may be added, entertained the same opinion. Whoever has attended experimentally to the subject of evaporation, must have been frequently struck with the anomalous nature of the results which the same course of experiments has disclosed. A sudden gleam of the Sun immediately quickens the evaporating power, and any alteration of wind will likewise modify the course of the results.

(485.) It is necessary, however, to limit the assertion to vessels whose differences of surface are not infinitely great, and whose local conditions are entirely the same. A surface of water contained in a vessel of finite dimensions, and placed in the midst of an open and arid plain, must necessarily undergo a more copious evaporation than if placed in the midst of a great lake, under similar circumstance of heat, of the sky, and of the wind. The reason, also, will be apparent when we consider that the vessel is surrounded by a drier air in the midst of the plain, than when encompassed by the waters of the lake, and must hence undergo a greater evaporation. And this remark may be employed as a useful caution when we endeavour to estimate the amount of evaporation from the sea, by the quantity of vapour raised in a given time from a vessel in a garden.

Principal causes which modify the results of evaporation. Temperature.

(486.) The two great causes, however, which influence evaporation, and modify its results, are the temperature and movements of the atmosphere, into the effects of which we must more particularly inquire. And first with respect to temperature. Every degree of heat seems to produce evaporation from water, nor can the lowest temperature, in a proper condition of the air, entirely destroy this power. Evaporation, indeed, as Dalton remarks, continues to act below the point of congelation as well as above it, and we owe to that profound inquirer, the best experiments we possess respecting the rate at which water evaporates under different degrees of heat. In an atmosphere perfectly dry and calm he obtained the following results.

TABLE CII.

Temperature.	Rate of Evaporation per Minute expressed in Grains.	Elastic Force of Vapour in Inches.
212°	30	30.00
180	15	15.15
164	10	10.41
152	8.5	7.81
144	6	6.37
138	5	5.44

Rate of evaporation proportional to the elasticity of the vapour produced.

Thus the rate of evaporation under the circumstances mentioned is found to be proportional to the elasticity of the vapour produced.

Least evaporation produced when air is perfectly quiescent.

A current of air accelerates it.

The more rapid the current the greater the evaporation, other things being the same.

Mr. Dalton's results.

Effects of currents.

(487.) Concerning the changes which the rate of evaporation undergoes in consequence of the air in contact with the evaporating water being either quiescent, or moving with different velocities over it, it may in the first place be remarked, that air in a state of perfect repose and under constant circumstances of temperature and pressure, produces the least possible degree of evaporation; and that, in such a condition of things, the vapour, as it forms, accumulates over the evaporating surface, and by successively checking the evaporating power, ultimately reduces it to nothing. But a current of air with whatever velocity it may proceed, by bringing new portions of air less saturated with humidity over the evaporating surface, must again renew the evaporating power; and thus the more rapid the current, the more rapidly, *cœteris paribus*, must the water disappear. As a proof of this we may adduce the important experiments of Mr. Dalton, who found, that at the temperature of the boiling point, the least evaporation took place from water, when the evaporating surface was placed in the middle of a room, with the doors and windows closed. Under these circumstances the rate of evaporation was 30 grains per minute. On placing the water in the chimney, with the doors and windows completely shut, the current of air existing in the chimney increased the evaporating power to 35 grains a minute. An increase in the fire, by augmenting the current in the chimney, raised the evaporation from 35 to 40 grains a minute; and by opening the windows of the room, and producing thereby a stronger current in the chimney, the force was increased from 40 to 45 grains per minute. Had the experiments been performed in the open air, and in a very high wind, the rate of evaporation would have been much greater. In air moving with an infinite velocity, as Biot remarks, the rate of evaporation would be infinite also.

Mr. Howard's example of influence of the wind.

An interesting example of the effects of the free action of the wind on the annual rates of evaporation at different heights is given by Mr. Howard. During three years in which the gauge was elevated about forty-three feet from the ground, exposed to the South-East, and subject to the free action of the wind in most directions, the annual average result was 37.85 inches. During other three years in which the instrument was lower and less exposed, the annual rate rose to 33.37 inches; and during another triennial period when the gauge was upon or near the ground, the yearly rates averaged only 20.28 inches.

(488.) In the next Table we have given Mr. Dalton's results at the successive temperatures recorded in it, with different velocities of the atmosphere, but in a perfectly dry state of the air. The three last columns of the Table show the quantity of vapour in grains driven off in a minute from a circular vessel of water six inches in diameter.

TABLE CIII.

Temperature.	Elastic Force of Vapour in Inches.	Evaporating Force in Grains.		
212°	30.000	120	154	189
20°	0.129	0.52	0.67	0.82
21	0.134	0.54	0.69	0.85
22	0.139	0.56	0.71	0.88
23	0.144	0.58	0.73	0.91
24	0.150	0.60	0.77	0.94
25	0.156	0.62	0.79	0.97
26	0.162	0.65	0.82	1.02
27	0.168	0.67	0.86	1.05
28	0.174	0.70	0.90	1.10
29	0.180	0.72	0.93	1.13
30	0.186	0.74	0.95	1.17
31	0.193	0.77	0.99	1.21
32	0.200	0.80	1.03	1.26
33	0.207	0.83	1.07	1.30
34	0.214	0.86	1.11	1.35
35	0.221	0.90	1.14	1.39
36	0.229	0.92	1.18	1.45
37	0.237	0.95	1.22	1.49
38	0.245	0.98	1.26	1.54
39	0.254	1.02	1.31	1.60
40	0.263	1.05	1.35	1.65
41	0.273	1.09	1.40	1.71
42	0.283	1.13	1.45	1.78
43	0.294	1.18	1.51	1.85
44	0.305	1.22	1.57	1.92
45	0.316	1.26	1.62	1.99
46	0.327	1.31	1.68	2.06
47	0.339	1.36	1.75	2.13
48	0.351	1.40	1.80	2.20
49	0.363	1.45	1.86	2.28
50	0.375	1.50	1.92	2.36
51	0.388	1.55	1.99	2.44
52	0.401	1.60	2.06	2.51
53	0.415	1.66	2.13	2.61
54	0.429	1.71	2.20	2.69
55	0.443	1.77	2.28	2.78
56	0.458	1.83	2.35	2.88
57	0.474	1.90	2.43	2.98
58	0.490	1.96	2.52	3.08
59	0.507	2.03	2.61	3.19
60	0.524	2.10	2.70	3.30
61	0.542	2.17	2.79	3.41
62	0.560	2.24	2.88	3.52
63	0.578	2.31	2.97	3.63
64	0.597	2.39	3.07	3.76
65	0.616	2.46	3.16	3.87
66	0.635	2.54	3.27	3.99
67	0.655	2.62	3.37	4.12
68	0.676	2.70	3.47	4.24
69	0.698	2.79	3.59	4.38
70	0.721	2.88	3.70	4.53
71	0.745	2.98	3.83	4.68
72	0.770	3.08	3.96	4.81
73	0.796	3.18	4.09	5.00
74	0.823	3.29	4.23	5.17
75	0.851	3.40	4.37	5.34
76	0.880	3.52	4.52	5.53
77	0.910	3.65	4.68	5.72
78	0.940	3.76	4.83	5.91
79	0.971	3.88	4.99	6.10
80	1.000	4.00	5.14	6.29
81	1.040	4.16	5.35	6.54
82	1.070	4.28	5.50	6.73
83	1.100	4.40	5.66	6.91
84	1.140	4.56	5.86	7.17
85	1.170	4.68	6.07	7.46

Preceding Table formed on supposition that no moisture previously exists in the air.

(489.) But this Table has been constructed on the supposition that no vapour previously exists in the air, a hypothesis which can never be verified in any condition of the atmosphere, since at every season, moisture more or less abounds in it. In cases where the elastic forces are considerable, the influences of this vapour are insensible, but at lower temperatures its amount must by no means be neglected. If we suppose the water of evaporation to have a temperature of 50°, we shall find the force of vapour at that temperature exactly $\frac{1}{80}$th of its force at 212°, and therefore, from what has been before advanced, the rate of evaporation ought to be $\frac{1}{80}$th also. If, however, at the time of observation, an aqueous atmosphere already existed to that amount, or, in other words, the air be completely saturated with moisture, no evaporation can possibly take place, and the amount of vapour must remain unchanged. But if the force of the aqueous atmosphere should be less than that which a complete saturation admits, there will be room for the evaporating power to become active, and a quantity of vapour, dependent on the difference of the temperature of the water and of the vapour already existing in the air, will be raised.

Mr. Dalton measures this moisture.

(490.) To measure the effect of this humidity of the atmosphere, Mr. Dalton endeavoured to discover the exact quantity of vapour existing at the moment of observation. He took a tall cylindrical glass jar, dry on the outside, and filled it with cold water fresh from a well. If dew were immediately formed on the outside, he poured the water out, and allowed it to stand some time to augment its heat, at the same time carefully drying the outside of the glass with a linen cloth. This operation was continued till dew ceased to be formed, when the temperature of the water and the force of vapour were determined. The experiment was performed either in the open air, or at a window, on account of the internal air being generally more humid than that which is without. Spring water being commonly, also, at about 50° of temperature, was made use of for the three hottest months of the year, but, at other seasons, a cold, artificial mixture was employed. To estimate the evaporating power, water was introduced into a tin vessel of a given diameter suspended from the arm of a balance, and the exact loss of weight from evaporation found. Then denoting the whole amount of the elastic force of vapour at the term of saturation corresponding to the observed temperature by f, and the actual force of vapour already existing in the air by f', Mr. Dalton found under all conditions of the atmosphere, whether perfectly quiescent or agitated by the wind, the rate of evaporation to be constantly proportional to

Rate of evaporation proportional to $f-f'$.

$$f-f';$$

or, in other words, that if the whole tension of the vapour at the temperature of the boiling point be denoted by F, and that at this same temperature the weight of water evaporated in a minute in dry air be denoted by m for a given unit of surface, the quantity of vapour to be obtained at any other temperature, but with the same conditions of repose or agitation of the air, will be expressed by the function

$$\frac{m\,(f-f')}{\mathrm{F}}.$$

(491.) The value of the coefficient m will of course be different under different circumstances of the atmosphere. In a calm and tranquil air, as our Table CIII. indicates, its value must be 120; in a moderate breeze 150, and in a high wind 180; so that denoting the results of evaporation under these different conditions by E, E′, and E″, we shall have

Formulæ for estimating the rate of evaporation on different velocities of the air.

$$\left.\begin{aligned} \mathrm{E} &= \frac{120}{30}(f-f') = 4\,(f-f') \\ \mathrm{E}' &= \frac{150}{30}(f-f') = 5\,(f-f') \\ \mathrm{E}'' &= \frac{180}{30}(f-f') = 6\,(f-f') \end{aligned}\right\}\ (\mathrm{V.})$$

(492.) These formulæ will enable us to resolve some interesting Meteorological problems. In the first place by knowing the functions f and f', that is the maximum tension of the aqueous vapour for the observed temperature, and the tension of the vapour existing in the atmospheric beds at the same time, and multiplying their difference by the coefficient depending on the state of the atmosphere as to wind, will at once determine the rate of evaporation. If we take the case when a moderate breeze prevails, and suppose the temperature 70°, and the amount of the observed humidity in the air to be 0.388 inches of the mercurial column, then the whole amount of the elastic force being 0.721 inches, we shall have

Example of rate of evaporation determined.

$$\mathrm{E}' = 5\,(f-f') = 5\,(0.721 - 0.388) = 1.665 \text{ grains},$$

being the rate of evaporation per minute from a circular surface of water six inches diameter and one inch deep, under the circumstances stated.

(493.) This may be regarded as an example of the direct use of one of the formulæ, but they may be all applied to other useful purposes. If we wish to determine the actual tension of the vapour really contained in the atmosphere at the time of observation, and we know by some previous experiment the rate of evaporation, and supposing, moreover, a high wind to prevail, we shall have

$$\mathrm{E}'' = 6\,(f-f'),$$

and from which may be deduced

$$f' = f - \frac{\mathrm{E}''}{6},$$

Example of the actual humidity of the air determined by aid of the rate of evaporation.

and which will therefore give a measure for the actual humidity of the air under the given circumstances of f and E″. If we suppose the first of these elements to be 0.524 inches, and the second 0.324 grains, the temperature, as the value of f indicates, being 60°, we shall obtain from the particular formula we have selected

$$f' = 0.524 - \frac{0.312}{6} = 0.524 - 0.052 = 0.472 \text{ inches},$$

and which may be regarded as an exact and simple means of determining the value of f'.

Whole tension of vapour if necessary.

(494.) We might also discover the whole amount of humidity corresponding to the term of saturation for the observed temperature, by previously obtaining the values of E and f'; but no real advantage would result from it, as we are already in possession of a better method of determining it, and even by a formula which will give us its value at any temperature.

Rate of evaporation influenced by density of the air.

(495.) The rate of evaporation is also influenced by the density of the air, increasing as that density lessens, and exhibiting its greatest degree of power in a vacuum. Mr. Daniell, in an ingenious course of experiments, has traced the relation between the increase of

Mr. Daniell's experiments.

the evaporating power and the diminution of the atmospheric pressure. For this purpose he enclosed in a glass receiver, upon the plate of an air-pump, a vessel with sulphuric Acid, and another with water, and by properly adjusting the surfaces of the two, was enabled to maintain, in the included atmosphere of permanently elastic fluid, an atmosphere of vapour of any required force; or, in the popular mode of expressing the same fact, the air could be kept to any degree of dryness. The density of the air also in such an arrangement could be varied and measured at pleasure. There are three methods of estimating the progress of evaporation in such an atmosphere; the first and most direct is, to find the loss of weight sustained by the water in a given time; the second, to measure by a thermometer, the depression of temperature of the evaporating surface; and the third to ascertain the Dew point, by means of the hygrometer.

His apparatus.

(496.) The receiver which Mr. Daniell made use of in his first experiment was of large capacity and fitted with one of his Hygrometers. A flat dish of 7½ inches diameter was placed under it, the bottom of which was covered with strong sulphuric Acid. The glass bell but just passed over it, so that the base of the included column of air rested everywhere upon the acid. In the centre of the dish was a stand with glass feet, supporting a light glass vessel of 2.7 inches diameter, and 1.3 inches depth. Water to the height of an inch was poured into the latter, the surface of which stood just three inches above that of the acid. A very delicate thermometer rested in the water upon the bottom of the glass, and another was suspended in the air. The sides of the vessel were perpendicular to its bottom, which was perfectly flat. The height of the barometer was 29.6, and the temperature of the water 56°. In twenty minutes from the beginning of the experiment, the Hygrometer was examined, and no deposition of moisture was found at 26°.

Successive experiments.

(497.) This being the greatest degree of cold which could be conveniently produced by the affusion of ether, Mr. Daniell repeated the experiment with a contrivance which admitted the application of a mixture of pounded ice and muriate of lime to the exterior ball of the Hygrometer. In this manner the interior ball was cooled to 0°, without the appearance of any dew. The temperature of the air and water in this instance was 58°, and the atmospheric pressure 30.5.

(498.) From this experiment, therefore, it appears, that in the arrangement above described, the surface of water was not adequate to maintain an atmosphere of the small elasticity of .068 inches. In what degree it was less than this, or whether steam of any weaker degree of elasticity existed, the experiment of course did not determine. We may reckon, however, without any danger of error, that the sulphuric Acid, under these circumstances, maintained the air in a state of almost complete dryness.

(499.) In a second experiment, the same trial was made with atmospheres variously rarefied. No deposition of moisture was in any case perceived, with the utmost depression of temperature it was possible to produce; and the state of dryness was as great in the most highly attenuated air, as in the most dense. In the higher degrees of rarefaction, however, the water became frozen.

(500.) In a third experiment, the water which had been previously exposed to the vacuum of the pump to free it from air, was weighed in a very sensible balance, before it was exposed to the action of the sulphuric Acid under the receiver. Its temperature in this situation was 45°, and the height of the barometer 30.4. In half an hour it was again weighed, and the loss by evaporation found to be 1.24 grains.* It was replaced, and the air rarefied till the gauge stood at 15.2; after the same interval of time the loss was found to be 2.72, but the temperature was reduced to 43°. The loss from evaporation, in equal intervals, with a pressure constantly diminishing one half, was found to be as follows:

Results.

TABLE CIV.

Pressure.	Temperature.		Evaporation in Grains.
	Beginning.	End.	
30.4	45°	45°	1.24
15.2	45	43	2.87
7.6	45	43	5.49
3.8	45	43	8.80
1.9	45	41	14.80
0.95	44	37	24.16
0.47	45	31	39.40

When the exhaustion was pushed to the utmost, the gauge stood at 0.07, and the evaporation in the half hour amounted to 87.22 grains. During this last experiment, the water was frozen in about eight minutes, while the thermometer under the ice denoted a temperature of 37°.

Correctio of these r sults for variation of tempe ature.

(501.) These results require, however, some corrections for the variations of temperature which took place during their progress. The rate ef evaporation having been proved proportional to the elasticity of vapour, we must estimate the latter from the mean of the temperatures before and after the experiments, and calculate the amount for some fixed temperature accordingly. This will afford us a close approximation to the truth, although from the last experiment we may perceive that the method of estimating the temperature of the surface cannot be absolutely correct. The next Table presents us with the former results corrected for the temperature of 45°.

TABLE CV.

Pressure.	Evaporation in Grains.
30.4	1.24
15.2	2.97
7.6	5.68
3.8	9.12
1.9	15.92
0.95	29.33
0.47	50.74
0.07	112.32

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* It will be remarked by referring to our Table CIII. that Mr. Dalton found the full evaporating force of water at the temperature of 45°, to be 1.26 grains per minute, from a vessel of six inches diameter.

Rate of evaporation inversely proportional to elasticity of incumbent air.

Notwithstanding the slight irregularity of the above series, there can be no risk in drawing from it the conclusion, that the rate of evaporation is, *cæteris paribus*, inversely proportional to the elasticity of the incumbent air. This increased evaporation with a diminished density of the air, will account for the high state of saturation in which the air of mountainous Countries is generally found.

Elasticity of vapour from water of constant temperature not changed by differences of pressure.

(502.) Mr. Daniell likewise endeavoured to discover if the elasticity of the vapour as it rose from water, varied in any degree with the pressure of the air, or whether any portion of the increased evaporation depended upon that variation. To determine this he placed the sulphuric Acid in a glass having nearly the same surface as the water, the two being arranged side by side, upon the plate of the air-pump, and covered with the receiver. By many successive experiments it was found, that the elasticity of vapour given off by water having a constant temperature, was not influenced by differences of atmospheric pressure.

Inquiry if temperature of evaporating surface is influenced by changes of density.

(503.) It is also a point worth inquiring in what degree the temperature of an evaporating surface is influenced by differences in the density of the air. To estimate this, Mr. Daniell attached a very delicate mercurial thermometer to a brass wire sliding through a collar of leathers in a ground brass plate. This was fixed, air tight, upon the top of a large glass receiver, which covered a surface of sulphuric Acid of nearly equal dimensions with its base. Upon a tripod of glass, standing in the Acid, was placed a vessel containing a little water, into which the thermometer could be dipped and withdrawn by means of the sliding wire, the bulb of the instrument being covered with filtering paper. At the commencement of the experiment, the barometer stood at 30.2 inches, the temperature of the air being 50°. On withdrawing the thermometer from the water it began rapidly to fall, and in a few minutes reached its maximum of depression. The following Table contains the results, the intervals of observation being twenty minutes each.

TABLE CVI.

Barometer.	Temperature of the Air.	Temperature of the Wet Thermometer.	Difference.
30.2	50°	41°	9°
15.1	49	37	12
7.5	49	34	15
3.7	49.5	31.5	18
1.8	49.5	28.5	21
0.9	49	24.5	24.5
0.4	49	23	26

(504.) Here then in an atmosphere, proved to be in a state of almost complete dryness, we find that at the full atmospheric pressure, the wet surface of the thermometer was reduced 9°. It is worthy of observation how small a quantity of water is necessary to produce this effect. We have before seen that a surface of 2.7 inches diameter, lost only 1.24 grains in half an hour, and which would only have amounted to 1.41 grains, had the temperature been 49°. The surface of the wet thermometer, Mr. Daniell remarks, could not have exceeded one-fiftieth of that of the evaporating vessel, and the maximum effect was produced in ten minutes, or one-third of the time, so that the weight of water evaporated in this case was not more than (.0094 grains) one-hundredth of a grain. It will be seen that the depression increased with the rarefaction of the air, but at a much slower rate. This increase is to be attributed, however, not to the increased rate of evaporation, but to the diminished heating power of the air. MM. Du Long and Petit, in their experiments upon the cooling power of air, determined it to be nearly as the square root of the elasticity; but whether the heat which it is capable of communicating to a cold body, follows the same progression, the experiments which we have here recorded, are not sufficient to determine. We may, however, conclude with certainty from them, that the temperature of an evaporating surface is not affected by the mere quantity of evaporation.

Dr. Bostock's horary rates of evaporation.

(505.) The only series of horary rates we are acquainted with are those of Dr. Bostock contained in the next Table, and are the averages of 149 experiments performed during single hours on different days.

TABLE CVII.

Months.	Rate of Evaporation in Grains per hour.	Months.	Rate of Evaporation in Grains per hour.
January....	0.287	July.......	0.983
February...	0.400	August	0.932
March	0.393	September..	0.555
April	.....	October	0.346
May.......	0.897	November..	0.369
June	0.930	December ..	0.392

Deductions from them.

The whole of Dr. Bostock's experiments embraced the result of 1188 hours, the mean evaporation being 0.501 grains per hour from a vessel of two inches diameter. Of these, 942 referred to the Winter, giving an average of 0.43 grains per hour, and 246 for the Summer, affording a mean of 0.77 grains per hour. The maximum evaporation in an hour amounted to 1.75 grains, and occurred on the 4th of August. The minimum evaporation was found on the 12th of November, when no loss of weight could be traced. The greatest Winter evaporation was found on the 28th of November, amounting to 1.08 grains, and the least Summer evaporation on the 5th of August, the very day succeeding the maximum evaporation;—another example of the sudden and apparently capricious change of the atmosphere.

Horary observations relating to the wind.

Of the horary observations which relate to the wind; Dr. Bostock observes, that the average of fourteen Winter observations, with the wind in a South or West point, gave 0.346 grains per hour. Of the same number of Summer observations, with the wind blowing between the same points, 0.882 grains. Of fourteen Winter observations, with the wind in a North or East point, 0.546 grains per hour; and of the same number of Summer observations, with the wind from the same points, 1.03 grains per hour.

How evaporation is influenced by height of mercurial column.

(506.) To discover in what way the rate of evaporation was affected by the height of the mercurial column, the barometric scale from 29.20 to 30.20 was divided into ten equal parts, and the same number of observations being made under each division, gave the following horary rates of evaporation.

TABLE CVIII.

Height of the Barometer.	Rate of Evaporation per hour in Grains from a Vessel of two inches diameter.
29.3	0.381
29.4	0.451
29.5	0.436
29.6	0.386
29.7	0.760
29.8	0.750
29.9	0.510
30.0	0.545
30.1	0.565
30.2	0.471

High and low barometer less favourable for evaporation.

It would seem from these experiments, though any deduction from them, from their limited nature, must be received with caution, that either a very low or a very high barometer is less favourable to evaporation than an intermediate state; a result, however, which is in some degree favoured by the fact, that the damp or wet weather commonly attendant on a low barometer is unfavourable to evaporation; and that when the barometer is high, the atmosphere may be supposed to be more nearly saturated with moisture, and therefore less disposed to receive any additional quantity.

Horary ol servations with respe to temperature.

(507.) Of the horary observations made with respect to the temperature of evaporation, Dr. Bostock has given the results in

TABLE CIX.

Temperature.	Rate of Evaporation per hour in Grains from a Vessel two inches diameter.
Below 40°	0.470
From 40° to 50°......	0.352
From 50° to 60°......	0.450
From 60° to 70°......	0.878
Above 70°	1.000

The apparent anomaly in the results for the temperature below 40° may be explained on the principle that the greatest degrees of cold are generally accompanied by North or East winds, which in other respects are the most favourable to evaporation.

Monthly observatio for Liverpool, Ken dal, Tottenham, and London.

(508.) Of the monthly observations which have been made to show the progressive rates of evaporation, we have those of Dr. Dobson, Mr. Dalton, Mr. Howard, and Mr. Daniell, which are contained in the several columns of the following Table.

TABLE CX.

Months.	Dr. Dobson's Mean Evaporation for 4 years in inches. Diameter of Evaporating Vessel 12 inches. Locality Liverpool.	Mr. Dalton's Mean Evaporation for 3 years in inches. Diameter of Evaporating Vessel 10 inches. Locality Kendal.	Mr. Howard's Mean Evaporation for 8¼ years in inches. Diameter of Evaporating Vessel 5 inches. Locality Tottenham.*	Monthly Mean Temperatures.	Mr. Daniell's Mean of 3 years in inches. Diameter of Evaporating Vessel 6 inches. Locality London.	Monthly Mean Temperatures.
January......	1.50 in.	1.008 in.	0.832 in.	36°.34	0.413 in.	36°.1
February.....	1.77	0.528	1.643	39.60	0.733	38.0
March	2.64	0.623	2.234	42.01	1.488	43.9
April	3.30	1.485	2.726	47.61	2.290	49.9
May.........	4.34	2.684	3.896	55.40	3.286	54.0
June.........	4.41	2.184	3.507	59.36	3.760	58.7
July.........	5.11	4.095	4.111	62.97	3.293	61.0
August.......	5.01	3.386	3.962	62.90	3.327	61.6
September	3.18	2.954	3.068	57.70	2.620	57.8
October	2.51	2.672	2.208	50.79	1.488	48.9
November....	1.51	2.055	1.168	42.40	0.770	42.9
December.....	1.49	1.484	1.112	38.71	0.516	39.3

Monthly evaporation follows nearly the mean temperature.

(509.) In these monthly results it may be perceived that the rate of evaporation follows in a general, but not uniform manner, the course of the mean temperature. In some years the evaporation receives a check in the Spring, from depressed temperature, but its energy is again restored by a renewal of heat. The frosts of Spring and of the latter months of the year also retard it.

Results Glasgo

(510.) The following Table exhibits the average elasticity of vapour in the atmosphere of Glasgow, and the rate of evaporation for several months of the years 1823, 1824, obtained by Dr. Hugh Colquhoun. We wish such observations could be extended.

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* In Mr. Howard's results, the evaporating gauge was at different heights from the ground.

TABLE CXI.

Year and Month.		Elasticity of Vapour in the Atmosphere.	Rate of Evaporation.
1823.	May..........	0.3113	0.1454
	June	0.2937	0.2746
	July..........	0.3077	0.2249
	August	0.3766	0.2143
	September	0.3596	0.1666
	October.......	0.3126	0.0782
	November	0.3020	0.0598
	December......	0.2431	0.0253
1824.	January	0.2531	0.0568
	February......	0.2314	0.0720

Evaporation for the four seasons.

(511.) According to Mr. Howard, the evaporation for the four seasons at Tottenham, with the corresponding mean temperatures, are as follows :

TABLE CXII.

Seasons.	Evaporation in Inches.	Mean Temperature.
Spring	8.856	48°.06
Summer	11.580	60.80
Autumn........	6.444	49.13
Winter	3.587	37.20

It will be seen from these results, that the rates of evaporation are not proportional to their corresponding mean temperatures; the Spring and Summer being in excess, and the Autumn and Winter in defect, arising from the comparative dryness of the air in the former seasons, and its dampness in the latter. It must be borne in mind, however, that Howard's gauge was not always at a constant height above the ground.

Annual rates of evaporation for London, Tottenham, Liverpool, Kendal, and Glasgow.

(512.) The following Table contains a few results of the annual rates of evaporation.

TABLE CXIII.

London	23.974	inches.
Tottenham	30.467	
Liverpool	36.770	
Kendal	25.158	
Glasgow	32.418	

Dr. Thomson is disposed to take 32 inches as the mean annual evaporation for Great Britain. He considers it to be less than this in a great part of Scotland, and a portion of England; but that it exceeds it considerably in the South-East of England, and probably also in East Lothian and Berwickshire.

Experiments on the actual surface of the earth. Hales, Watson, Dalton, and Hoyle.

(513.) But few observations have been made on the rate of evaporation from the actual surface of the Earth. Dr. Hales calculated that moist earth threw off only $6\frac{2}{3}$ inches annually, but this calculation must be far below the truth. Dr. Watson, Bishop of Llandaff, found in a dry season that there evaporated from a grass-plot closely mowed, about 1600 gallons in an acre per day. In the years 1796, 1797, and 1798, Mr. Dalton and Mr. Hoyle undertook an investigation of the subject. They prepared a cylindrical vessel of tinned iron, ten inches in diameter, and three feet deep. Two pipes were inserted into it and turned downwards, for the water to run off from it into bottles. One of the pipes was near the bottom of the vessel, the other was an inch from the top. This vessel was filled up for a few inches with gravel and sand, and the rest with good fresh soil. It was then put into a hole of the ground, and the space around filled up with earth, excepting on one side, for the convenience of attaching bottles to the two pipes. The earth was then moistened with water. For the first year the soil was bare on the top, but during the two succeeding years it was covered with grass. A regular register was then kept of the quantity of water that ran off from the surface of the earth by the upper pipe, and also of the quantity which descended through the column of earth and passed through the lower pipe. A rain-gauge of the same diameter was planted close to the apparatus to find the quantity of rain. The mean result of three years gave 25.158 inches, to which five inches for dew being added, gave for the mean annual evaporation from earth at Manchester 30.158 inches. Mr. Leslie estimates the daily exhalations from a sheltered spot in Winter at 0.018 inches, and in Summer 0.048 inches; but this will only afford 12 inches at a mean rate in the year; and is evidently below the truth. As far as our knowledge at present goes, it appears that the evaporation from water is the greatest, from the grassy surface of the earth, probably, next, and from bare earth the least.

Leslie.

Dalton's experiments on the quantity of water in a given depth of earth.

(514.) Connected with this subject Mr. Dalton undertook some experiments to determine the quantity of water in a given depth of earth, when the soil is at the point of saturation. For this purpose he took a quantity of garden soil that had been soaked with rain a day before, and pressed it into a crucible. It was then exposed to a moderate heat till it appeared of the same moisture as garden soil two inches deep in dry summer weather. Afterwards it was exposed to almost a red heat till it became a perfectly dry powder. In the former case it lost one-twelfth of its weight, and in the latter one-third. When it had lost one-sixth, it did not appear too dry to support vegetation. When it had lost two-ninths, it seemed like the top soil in summer. Hence Mr. Dalton concludes, that every foot of earth in depth so saturated, contains seven inches of water, and that it may part with one-quarter, or even one-half of it, and not be too dry for supporting vegetation.

Evaporation of snow.

(515.) Experiments on the evaporation of snow are by no means numerous, and the Philosophers of Northern Countries would perform an acceptable service by attending in some degree to it. It is carried on in some conditions of the atmosphere with great rapidity and power. Howard mentions a case wherein the vapour arising from a circular area of snow of five inches diameter, amounted to 150 grains from sunset to sunrise in January, and 50 grains more by the following evening, the gauge being exposed to a smart breeze on the housetop. An acre of snow, under such circumstances, would hence evaporate, in the course of twenty-four hours, the enormous quantity of nearly 64,000,000 grains of moisture. Taking only the portion evaporated during the night, a thousand gallons of water were raised from the surface referred to. We may hence see why a moderate fall of snow sometimes entirely disappears

Curious phenomena.

during a succeeding Northerly gale, without the least sign of liquefaction from the surface. It is worthy of observation, also, that in deeper snows, the surface sometimes becomes curiously grooved and channelled by the wind acting unequally on it and thus promoting unequally the evaporating power. This phenomenon is best observed around the trunks of trees and near the interstices of palings, or wherever a stream of air acquires an increased force in a particular direction. Wilson found snow to evaporate at 27°.

Evaporation of ice.

(516.) Of experiments made on the evaporation of ice the principal are those of Mr. Dalton. A given quantity of water was allowed to freeze in a tin vessel of six inches diameter. The vessel and ice were then weighed together, and exposed in the open air for a certain time, and the loss of weight found. The following are his results.

TABLE CXIV.

Time of Observation.		Loss by Evaporation in grains.	In hours	Rate of Evaporation per minute in grains.	Wind.	Temperature of Air.
Nov. 5,	at Night	110	9	0.20	N.E. brisk.	28° to 31°
5,	at 10 A.M.	25	1½	0.33	N.E. mod.	32
29,	at 1 P.M.	24	1¾	0.23	Calm.	31
	P.M.	84	9½	0.15	——	30
30,	at Night	94	9	0.17	N.E. mod.	31
Dec. 19,	P.M.	75	8	0.16	N.E. calm	26 to 28
	At Night	33	11	0.05	Calm.	29
20,	A.M.	21	2	0.175	W. mod.	31

Of Polar Regions.

Of Glaciers.

According to M. Schuebler the evaporation from ice sometimes exceeds that of water. In the early part of January he found it to be twice as great as from an equal surface of water in the middle of February, during mild, cloudy weather. Gay Lussac has proved the evaporation of ice to go on at two degrees below the zero of Fahrenheit's scale. The great beds of ice in the Polar regions must therefore exert a considerable influence on the humidity of the atmosphere; and the process of evaporation wastes also the glaciers of the Alps, and even the *Mer de Glace* must feel the influence of its power.

Evaporation not always suspended in rain.

Less on those days in which rain falls.

(517.) It has been remarked, that evaporation is not always suspended during rain. Howard has proved this by direct experiment. Its rate, however, is usually much less on those days in which rain falls, and it is liable to a rapid increase immediately after. Howard, also, found, that an excess in the rate of evaporation is sometimes found to precede rain.

Suspended during formation of dew.

(518.) Evaporation must be suspended when dew begins to form, as it would be absurd to suppose the air can both give and receive moisture at the same moment, when in immediate contact with the evaporating surface.

Affected by calm preceding change of wind.

(519.) The calm which often attends a change of wind very sensibly lowers the rate of evaporation. The rate also diminishes on the passing off of a wind which has blown steadily for some days.

Checked by current of moist air.

(520.) Sometimes evaporation is checked by a current of air highly charged with moisture passing over the spot on which the observation is made, even though no rain be the result.

(521.) The most intense cold, yet observed, is insufficient of itself to prevent the formation of vapour.

Greatest evaporatio observed b Howard i a single day.

(522.) The greatest evaporation ever observed by Howard, in a single day, occurred on the 17th of May, 1809, and amounted to 0.39 inches, with the wind from South-East, and a mean temperature of 67°.

Theoretic attempts t estimate quantity evaporatio

(523.) Attempts have been made to estimate theoretically the mean daily evaporation, and, among others, by Dr. Young, who assumes it equal to the tabular number representing the elasticity of the vapour, sometimes exceeding and sometimes falling short of it about one-fourth. Dr. Anderson, also, in virtue of a hypothesis that the mean point of deposition is six degrees below the mean temperature, has contrived a formula for the same purpose, which seems to agree pretty well with observation. By assuming t for the mean temperature, and f_t, ϕ_τ for the elastic forces of vapour corresponding to the temperatures t and τ, the value of τ being $t - 6$, he deduces the formula

Andersoı formula same.

$$E = 365\left(f_t - \phi_\tau\left(1 + \frac{t - \tau}{447.4 + \tau}\right)\right) \dots\dots \text{(W)}$$

for the mean annual evaporation; or the expression

$$e = f_t - \phi_\tau\left(1 + \frac{t - \tau}{447.4 + \tau}\right)$$

for the mean daily evaporation, or nearly

$$e = f_t - \phi_\tau.$$

Exampl

(524.) Suppose, by way of applying this formula, we assume the mean temperature of London to be 50°, we shall then obtain by means of formula (W)

$$E = 365\left(f_t - \phi_\tau\left(1 + \frac{t - \tau}{447.4 + \tau}\right)\right)$$
$$= 365\left(0.37345 - 0.30384\left(1 + \frac{50 - 44}{447.4 + 44}\right)\right)$$
$$= 24.05 \text{ inches.}$$

Remarl able co cidence

And we have before seen, that Mr. Daniell found it from actual observation to be 23.974 inches, which is certainly a remarkable coincidence.

(525.) As a more convenient approximation he further transforms his formula into

$$E = 365\left(f_t - \frac{81}{80}\phi_{t-6}\right),$$

for the mean annual evaporation, or

$$e = \left(f_t - \frac{81}{80}\phi_{t-6}\right)$$

for the mean daily evaporation.

We may hence calculate approximatively the mean annual evaporation for each geographical parallel. Such formulæ, however, in the present condition of our knowledge, must be strictly received as approximations, and as such they are to be very highly valued.

Equa temp in tw feren not s cient mak of ev ratio

(526.) We conclude this interesting subject with the observation, that equality of temperature alone in two different years is not sufficient to allow us to infer that the rates of evaporation in those years are the same. With the same average temperature through all the months of the year, the different velocities of the air will at once introduce diversities of a very considerable kind. Indeed, if equality of temperature alone could determine the rate of evaporation, we might then suppose the equal temperatures found in the Spring and Autumnal months, would afford equal degrees of

Examples.

evaporation, but this we know not to be the case. Howard gives an example in point for March and October 1807, when the temperature of each month was just 42°, but the rates of evaporation were respectively 2.66 and 1.86, the difference being occasioned by the increased humidity of the air in the Autumnal months retarding the evaporating power.

Rain.

Rain.

(527.) The humidity so constantly afforded to the air by the process of evaporation, is returned again to the Earth, principally by the agency of Rain. A variety of theories have been proposed to account for the formation of Rain, for the phenomena disclosed in its descent, and for the many diversities which it presents in the different climates of the Earth; but none seemed to account for it on principles at once simple, satisfactory, and general, before that advanced by Dr. Hutton of Edinburgh. In this theory, Rain was supposed to result from the mingling together of great beds of air of unequal temperatures, differently stored with moisture, and the opinion has been adopted by Dalton, Leslie, and other distinguished men.

Theory of Hutton.

Remarks on saturation of air.

(528.) We have before seen that a volume of air of a given temperature, can be charged with only a limited portion of humidity, and that so long as the temperature remains unchanged, the moisture cannot be augmented. We also know, that air in the act of cooling, approaches to a state of saturation, and is disposed to part with some of its humidity; and on the contrary, that when heat is gained at any time by it, the power of receiving more moisture is at the same time obtained. We moreover know, that while the union of two volumes of unequal temperature must chill the one and warm the other, the former will resign some of its moisture, and the latter be disposed to receive it; and had the order of Nature permitted these opposite conditions of humidity and temperature to be precisely balanced, the united volume might have preserved its moisture unchanged, and no portion of the vapour whatever have been rendered visible. We have seen, however, that while the temperature slowly mounts by uniform arithmetical degrees, the moisture necessary for saturation ascends in a more rapid geometrical form; and that though two saturated volumes of unequal temperatures, may by their union afford a mean degree of heat, a mean degree of moisture cannot result, but some quantity will be found in excess, beyond what the mean temperature requires. This quantity, sometimes more and sometimes less, according to the temperatures of the mingling volumes, must be discharged in the shape of Rain; for the moisture which the air cannot support, ought of necessity to descend.

Temperature and humidity do not increase by the same law.

Consequences of this.

Graphical illustration of Hutton's principle.

(529.) A mode of illustrating this subject graphically was devised by Hutton, as follows. Let the abscisses A B, A B′, fig. 7, denote the temperatures of two equal portions of air, and the ordinates B C, B′ C′, the quantities of humidity belonging to them, the curve C F C′ passing through the extremities of the ordinates, being convex to the axis A B′. If now the extremities C C′ be joined, and B B′ be bisected in D, the perpendicular D E will denote the mean arithmetical measure of the moisture contained in the mingled volumes, and D F the actual quantity which the temperature A D can support in entire saturation, leaving E F for the measure of the moisture precipitated by the union.

Numerical examples.

(530.) A numerical example or two, may, however, more clearly explain this simple but interesting principle. Let it be required to mingle two volumes of air of the temperatures of 40° and 60°, each being saturated with humidity. The force of vapour at these temperatures are known to be respectively 0.263 and 0.524 inches of the mercurial column. The compound mixture will evidently have a mean temperature of 50°, and the mean of the elastic forces is at the same time 0.393 inches of the same column. But if we now inquire whether air at the temperature of 50°, requires an elastic force of this last-mentioned magnitude to saturate it entirely with vapour, we shall find that it does not; and that at the mean temperature here referred to, the measure of entire saturation is really 0.375 inches of quicksilver. The difference of the two columns, or 0.018 inches of mercury, is hence the amount of moisture that must ,be precipitated in some way or other from the compound mass.

Measure of moisture precipitated.

Precipitation not constant for equal differences of temperature.

(531.) To prove, moreover, that this precipitation cannot be constant for equal differences of temperature, let us further take the example of the temperatures 60° and 80°. In this case we shall find the elastic forces to be 0.524 and 1.000; and that at the mean temperature of 70°, the force of vapour is 0.721 inches. But the mean of the two elastic forces is 0.762, thereby proving that a quantity of vapour corresponding to 0.041 inches of the mercurial column, must be discharged the moment the aerial volumes are united.

Objection to the theory.

(532.) An objection may, however, be started, that the quantity of moisture which can at any time be discharged by such an union of masses of air, is by far too small to account for the actual precipitations of humidity which take place; and the example of the mean temperature of the lowest atmospheric stratum may be referred to as a proof, that were it to discharge, as Leslie expresses it, by some internal change of its constitution, its whole store of moisture, not more than five inches of water would be deposited; and that the atmosphere must therefore deposit five or ten times as much humidity in the course of a year, as it can at any one time hold in solution. But it should not be forgotten, that since only a very minute portion of the vapour contained in any of the atmospheric columns is at any time separated from the air, precipitation and evaporation must rapidly succeed each other, and that hence moisture is in some degree restored, as soon as it is discharged. In addition to this it should be also borne in mind, that in the currents which exist at all times in the air, and which bring into union volumes of very different temperatures, we are by no means to calculate on the discharge of *one* atmospheric column alone. The atoms of air which have discharged their watery store over a given spot, pass on, and are succeeded by others resulting from another union, thus adding the humidity which they are capable of discharging, to the Rain which has before descended.

Answered.

Rain should not always result from the union of atmospheric currents. Examples.

(533.) The order of Nature, however, requires, that Rain should not always result from the mingling together of opposite currents, and the theory before us amply confirms it. Two volumes of the temperatures of 50° and 60° may be blended, one of which contains vapour denoted by 0.2 inches of mercury, and the other by 0.3, the mean being 0.25; whereas the quantity necessary for entire saturation, at the mean temperature of 55°, is 0.443. In such a case it is obvious no precipitation can take place. One volume, again, may have a temperature of 52°, and be in a state of entire saturation, its elastic force being 0.401; but the volume to be united to it, with a temperature of 70°, containing moisture equivalent only to 0.589. The mean amount of moisture will therefore be 0.495, whereas the humidity necessary to produce saturation, at the mean temperature of 61°, is 0.542, so that no precipitation can take place. But in cases where the mingling volumes are both entirely saturated, however small may be the difference of their temperatures, some condensation dependent on that difference must take place. It is evident, indeed, that combinations of this kind may be endless, the absence of precipitation, as well as the amount of it when it takes place, depending on circumstances so varied and uncertain, as to afford, on the one hand, a shower so gentle as hardly to bear the designation of Rain, and on the other to supply the torrents which occasionally deluge the Tropics. Not only the existing state of moisture in the mingling columns must be subject to innumerable changes, but their different degrees of heat must be altered also; the elevation of their mean temperature too, as well as the extent of combination which takes place among all the moving volumes, must impress necessarily on the whole of the phenomena the greatest diversity. So varied, indeed, are all these conditions in the great volume of the atmosphere, that snow may be formed at great elevations, which descending into the lower regions of the air, must reach the ground at length in the shape of Rain. On the other hand Rain may be sometimes formed in the upper regions, and become frozen in its descent. Precipitation may also be actually going on above, without any indications of Rain below, the moisture entirely disappearing by the increased warmth of the lower strata.

Some precipitation must take place however small may be the difference of temperature.

Such combinations infinitely diversified.

Inquiry into the truth of the theory.

(534.) The great test, however, of a theory is its conformity to Nature, the capability it has of accounting for the diversified conditions which appear to attend on the phenomenon of Rain,—its generality,—the regularity which appears to characterise it in one region, and its great uncertainty in others; and, moreover, the exceptions which sometimes appear to take place to its descent altogether.

This theory will account for the generality of Rain.

(535.) We may, in the first place, remark, that it will account for the generality of Rain. The only conditions, as we have before seen, necessary for the formation of Rain, are those of unequal temperature and humidity, both of which must exist in every possible degree on a surface so exceedingly diversified as the Earth's. We have before remarked, in tracing the phenomena of vapour, how very variable is its distribution, from the unequal surfaces of land and water which prevail, the mountains, woods, and deserts, which by modifying the temperature, tend to produce a greater or less saturation of the atmospheric columns; and as we shall hereafter see, the great effects of variable winds in transporting this humidity in every direction, and by numberless currents in every locality and at every altitude, blending together the vapour raised in different climes, and thus producing, according to the theory that has been advanced, sufficient causes for precipitations of rain more or less abundant in every zone. Over all the globe, therefore, Rain should occasionally happen, and with greater diversity as the disturbing forces are more considerable. In places situated near land and water unequally distributed, and where the atmospheric strata are much broken and interrupted, either by their contact with the irregular masses rising from the ground, or by the unequal temperatures which separate the different waters of the Globe, variable Rains should be most abundant.

(536.) Again, in those regions of the Earth in which the movements of the atmosphere are more uniform, we may naturally look for a greater uniformity in the descent of Rain. The great atmospheric currents produced by the trade-winds, must in some region or other produce a mixture of different portions of the fluid mass, and if Rain be the result, we must conclude that the mingled masses of air have been sufficiently saturated with moisture, and of different temperatures. This we know to be the case, there being periodical descents of Rain which harmonize with the causes here assigned to them.

Periodical descents o Rain.

(537.) According to the theory also under consideration, the Islands situated under the line in the Indian Ocean, should form to themselves conditions of periodical condensation, corresponding to the diurnal influence of the Sun, and the nocturnal motions which take place in the air. And this is observed to be the case. The sea and land breezes which every day occur, by the blending together of opposite currents, occasion, in conditions favourable to the condensation of vapour, either always, or at particular seasons, the daily phenomenon of Rain. These conditions, it is true, are not always to be found where the periodical currents exist; but it cannot be unreasonable to suppose that a sufficient supply of aqueous vapour exists in those regions in the air, nor that in the great system of diurnal currents, there may not be some portions mingled together of unequal temperatures.

(538.) In like manner, Dr. Hutton accounts for the periodical rains which occur upon the different coasts of the Peninsula of India. In the great range of the tropical regions of Africa and Asia, the rivers indicate that it rains in the Summer solstice, and that fair weather results from the removal of the heating cause. The air elevated by the intense power of the solar heat, has its place supplied by that which has been transported from the neighbouring seas. But arrived here upon a heated continent, this humid air must be elevated into the higher regions of the atmosphere, and either be transported from thence towards the Poles, there to be gradually condensed as the depression of temperature goes on, or it must fall again in rain on the surface from which it was raised. On the first supposition, no Rain should be found to take place in these regions in the Summer; and the rivers, by which we are alone able to judge of the phenomenon, should be found in their lowest state after that season. But, as all authorities concur in stating the opposite to this to be true, the rivers being then swollen, it follows that the humid atmosphere which has advanced from the sea, must have its vapour condensed upon the heated continent at the time of the Summer solstice. Indeed it is a well-known fact, that the heavy Rains which fall in India, always take place during the shifting of the Monsoon, and while they last the winds are always variable.

(539.) The Summer Sun, however, which proves a cause of Rain in some regions of the Earth, in which neighbouring seas affording a great evaporation exist, in other regions becomes the cause of drought, where the evaporating power is less, or is supplied from a more distant source. A continent less abundantly supplied with vapour than the tropical parts of Africa and Asia, when heated by the full power of the Summer Sun, ought to be more disposed to drought than Rain, unless some transient streams of air, properly charged with moisture, should reach the place, and, by being blended, occasion the descent of Rain. Such a phenomenon, however, could not be regarded as a general season of Rain. On the decline of Summer, the air approaches saturation, and becomes disposed to produce Rain with every mixture resulting from unequal temperatures. Hence a source of Autumnal Rains and Winter snows, which may fall with all the uniformity of tropical Rains, and the effect is manifested in the regular covering of the Northern continental regions with snow, an event which happens with so much constancy, that it may be regarded as analogous to a periodical Rain.

Cases where no Rain exists, explained.

(540.) We have before remarked, that precipitation is not at all times the result of the mingling together of opposite currents, and the Sahara of Africa, the low coasts of Caraccas, Egypt, and a portion of the coast of Peru have been instanced as places where it never rains. According to some authorities, a South-West wind constantly prevails at the latter, although, according to others, it varies between the South-West and South South-West points of the compass. Now a wind constantly uniform, or nearly so, must either produce constant precipitation, or no Rain at all; and since the prevailing wind here alluded to, passes from a colder into a warmer region, and thus becomes more and more removed from the term of saturation, it follows that the constancy of the wind insures the permanence of the result. But although no Rain falls in the lower regions of Peru, the atmospheric currents, as they move on, must at length reach the lofty summits of the Andes, where meeting with a diminished temperature they undergo condensation, and occasion those almost constant precipitations with which those mountainous regions abound.

Rare occurrence of Rain in trade-winds.

(541.) The rare occurrence of Rain in the constant trade-winds, may also be regarded as an indirect confirmation of the theory. The aqueous vapour rising into the higher atmosphere, and flowing to the North and South, without accumulation, on account of the steadiness of the temperature and the uniform direction in which the vapour moves, occasions no formation of Rain. But beyond the boundaries of these winds, precipitations are very abundant. Not only the vapour becomes subject to a rapidly decreasing temperature, but the variable winds are constantly bringing atmospheric masses, possessed of the necessary conditions of humidity, into union with each other.

(542.) That the greater portion of the Earth should be found destitute of Rain, would certainly militate against the theory we have been anxious to explain; but that a few spots, having no diversity of climate, should be found without it, confirms rather than invalidates it. In such instances the conditions necessary for the precipitation of humidity do not exist.

Objections of Howard to Hutton's Theory.

(543.) The theory of Hutton has, however, been in some degree questioned by Mr. Howard; but while this distinguished Meteorologist seems to doubt the possibility of an intimate mixture of large masses of the atmosphere, to the extent which the hypothesis of the Scotch Philosopher requires, and that in Summer different currents may be detected, flowing "quietly" over each other, without any "extraordinary precipitation, or, in some cases, without any turbidness at all, during several subsequent days of fair weather," yet he afterwards admits as "matter of experience, that the contact and opposition of different currents, charged with aqueous vapour and differing in temperature, is largely concerned in the production of our vernal and estival Rains." And with respect to the absence of precipitations in Summer, under the circumstances referred to, we are by no means certain that either the conditions of humidity or temperature, necessary for the formation of Rain, existed at the time; and we have before proved, that not every union of the atmospheric columns will of necessity produce it. Mixture, he thinks, may take place to a certain degree and accelerate precipitation, but he cannot regard it as "a *necessary* previous condition." He considers "the great and universal cause of Rain in our latitudes, to be the *depression of the temperature of vapour alone;*" whereas, in such an Island as Great Britain,—and we would by no means be supposed to limit the assertion to that little spot,—the very seat as it were of variable winds, and consequently of the motion of masses of air unequally stored with vapour, and of unequal temperatures, the theory of Hutton seems most abundantly confirmed;—"frequent showers,"[*] as Howard observes, "without extreme quantities of Rain falling at one time—the climate of the country inclining towards moisture." We may add here, also, what is matter of common notoriety, that steady dry weather is always accompanied by some uniform direction of the wind, whereas in rainy weather the winds are unsteady and variable.

There ought to be a diminution of Rain from the Equator to the Poles.

(544.) Amidst the seeming diversities, however, which characterise the descent of Rain, and which impress on particular localities, qualities which seem to set all investigation at nought, we may, nevertheless, infer from those general inquiries before advanced respecting the distribution of moisture, that the maximum descent of Rain ought to be found in the Equatorial regions, and that apart from all the disturbing causes which more or less influence its formation and descent, there ought to be a diminution in its quantity from those regions to the Poles.

Inquiry into this diminution.

(545.) In a general way we may be said to know the mean quantity of moisture existing in the different atmospheric columns for all the parallels of latitude; and that since the cause of the descent of Rain may be resolved into temperature only, we might determine its whole amount at a given place, provided we knew all the varied circumstances of temperature to which the atmosphere above it is subject. But the present con-

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[*] Some places have obtained a particular character for Rain, and among others Plymouth. The following rhymes are popular in the West, and though their Author has attributed to each of the great Cardinal winds, the power of bringing Rain, yet the Philosopher, bound by more rigid rules than the Poet, will at once recognise in them a confirmation of the theory of Hutton. At Plymouth, the winds are very variable, but the prevailing one is South-West for by far the major part of the year; and at Penzance, an equally variable climate, and not a degree and a half to the West, the prevailing wind, according to the accurate Tables of Mr. Giddy, the Curator of the Royal Geological Society of Cornwall, is North-West. Here then are two winds, to say nothing of the others, or of the peculiar configuration of the land, which by their union must prove constant sources of Rain to the whole of the peninsula over which they pass. The theory of Hutton, however, does not rest on a single example. Innumerable instances might, if necessary, be found.

The South wind always brings wet weather;
The North wind, wet and cold together.
The West wind always brings us Rain;
The East wind blows it back again.

If the Sun in red should set,
The next day surely will be wet;
If the Sun should set in grey,
The next will be a Rainy day.

dition of our knowledge will not enable us to estimate the temperature of the different atmospheric strata on a given day; and hence all that we can do, must be to compute the probable quantity of Rain, on the supposition that some general circumstances of temperature influence the atmosphere throughout. Under conditions like these, precipitations more or less abundant, according to the mean conditions of vapour existing in the different atmospheric columns, will be the result.

Relation between evaporation and rain and dew.

There must be, moreover, a relation of some kind between the vapour imparted by evaporation to the air, in a given time, and the humidity discharged in the shape of Rain and dew from it; but whatever that relation may be, it hardly follows in the troubled volume of the atmosphere, that it is constant even for the same latitude. There is a mean evaporation, and the air will support in a mean state, a given portion of vapour; and as we have before remarked, that vapour is always very much less than the mean result of evaporation affords. The whole amount of evaporation, therefore, being some multiple of the vapour contained in the air at a given time, we may denote the relation by the equation

$$E = m\phi,$$

where E denotes the whole amount of evaporation, m the quantity of moisture contained at one time in a column of air when entirely saturated, and ϕ a function whose value is dependent on the relation which the element m bears to E.

Anderson's mode of computing the rain in every latitude.

(546.) By making the function ϕ constant for every latitude, Dr. Anderson supposed that we might approximate in some degree to the mean amount of Rain in every latitude, by multiplying the aqueous columns which represent the columns of vapour existing in every latitude by it. In this way he computed the Table he has given in his able Article on Hygrometry before quoted, and in which he makes the Equatorial Rain amount to 73 inches, the rain in the parallel of 45° to 29¾ inches, and that at the Pole 11½ inches nearly. These results, however, as Brewster has remarked, are far from approaching the truth; and that supposing the formula of temperature to be corrected on which the computation is founded, it will even be then further removed from the truth, as the annual amount of Equatorial Rain would then only amount to 64½ inches, whereas, as we shall presently see, it is really much greater.

Another theoretical method.

(547.) A formula, contrived with a similar object in view, has been also given in the Article Physical Geography, contained in the Supplement to the *Encyclopedia Britannica*, in which the author supposes 83 inches to be the amount of the Equatorial Rains, and 8 that of the Polar, the formula thus assuming the shape of

$$83\ (\text{rad.} - \text{sin. lat.}) + 8 \ldots\ldots (X);$$

but this will be found to deviate very widely from the truth within the Tropics.

Humboldt's results for several latitudes.

(548.) Humboldt with more propriety fixes the Rain at the Equator, and in three several latitudes, as in the following Table.

TABLE CXV.

Latitude.	Mean Annual Depth of Rain.
0°	96 inches.
19	80
45	29
60	17

Doubt if tropical Rains are sufficient. Another Table for different latitudes.

But even here it is doubtful whether the amount of the tropical Rains is sufficient,* if the results of the next Table can be relied on.

TABLE CXVI.

Place.	Latitude.	Amount of Rain in inches.
Coast of Malabar. .	{ Mean latitude about 11½° N. }	123.5
Granada	12° N.	126
Cape François	19° 46′ N.	120
Calcutta.	22° 23′ N.	81
Rome	41° 54′ N.	39
England	50° to 55° N.	31
Petersburgh	59° 16′ N.	16
Uleaborg	65° 1′ N.	13½

Remarks on the gr anomalie On the te perature and amo of Rain.

(549.) Such anomalies as these may well inspire us with caution respecting theoretical assumptions framed independent of observations. The relations of temperature, which seem to guide other phenomena with accuracy within some tolerable limits, here absolutely forsake us; and we cannot, with any propriety, connect either the Rain at the same place with its average mean temperature, or, passing from one geographical parallel to another, trace any visible relation between the mean temperatures of those parallels, and the average precipitations of Rain upon them. If we take the results of an excellent series of observations made on the Malabar coast from 1810 to 1823 inclusive, as an example of the prodigious aberrations which the Rain undergoes, while the annual temperature oscillates within very moderate limits, we shall have a striking instance of the truth of the remark. The annual results both of the Rain and of the temperature are contained in the next Table.

Observ tions fo Malaba

TABLE CXVII.

Date.	Annual Amount of Rain in inches.	Annual Mean Temperature.
1810	125.90	80°.16
1811	104.90	80.13
1812	102.70	80.50
1813	93.85	80.35
1814	115.10	78.56
1815	133.40	. . . . .
1816	100.00	78.61
1817	136.70	79.00
1818	169.19	81.00
1819	135.47	80.78
1820	147.18	80.92
1821	98.44	82.25
1822	145.60	81.50
1823	121.67	82.00
Mean .	123.50	80.4

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* The inhabitants of our temperate climes have a sort of timidity respecting the amount of tropical Rains. Malte-Brun remarks, that "the European born to the North of the Alps, is ready to form a false idea of the character of the zone lying between the fortieth and twenty-fifth degrees of latitude." With how much greater reason might this be said with regard to the whole of the Equatorial regions.

Great aberrations exhibited by this Table.

Here there are deviations between the results of two years amounting to more than 75 inches of Rain, at a time when the difference of the mean temperature of the same years does not amount to a single degree. And so also with deviations from the average mean temperature of the whole, not amounting to two degrees of Fahrenheit's scale, there are differences from the average result of Rain exceeding 45 inches.

Contrasted with the observations of Dalton at Manchester.

(550.) As a contrast, however, to these results for the Malabar coast, let us take the case of Manchester as recorded by Dalton in the following Table, and we shall find that with quite as much uniformity in the mean results of temperature, we have a much higher degree of regularity in those of Rain. The greatest deviation from the mean temperature amounts only to 2.3, and that of the Rain but to 7.689, just a sixth part of that found in the Tropics.

TABLE CXVIII.

Years.	Mean Temperatures.	Mean Results of Rain.
1802	47.4	35.737
1803	47.2	27.472
1804	48.2	29.310
1805	48.0	27.542
1806	47.5	33.495
1807	47.0	....
1808	47.6	31.156
1809	47.3	....
1810	47.4	....
1811	49.3	37.726
1812	47.1	34.000
1813	48.3	33.828
1814	45.4	31.340
1815	46.2	37.506
1816	47.2	40.285
1817	48.5	36.412
1818	49.7	34.566
Mean....	47.6	33.596

Greater probability of arriving at correct conclusions respecting Rain in temperate regions.

There seems a greater probability, therefore, of arriving at correct conclusions respecting the phenomena of Rain in the temperate regions of the world, than in those of the Tropics. Mr. Howard has remarked with regard to the atmosphere of London, that the warm years are uniformly dry, or below the average in Rain, and the cold ones uniformly wet, or above the average; and that there is probably in this region of the Earth a close connection between the mean temperature of many years and the Rain at the Earth's surface which attends them.

Schow's comparison of amount of Rain of Countries North and South of the Alps.

(551.) That the Rain, however, does in some way or other decrease with the latitude is apparent from the comparison of what may be termed neighbouring districts. In Schow's inquiries concerning the two great divisions of Europe situated to the North and South of the Alps, he fixes at 25 inches the mean annual amount of Rain for the former, and 35 inches for the latter, although these numbers must not be taken as measures of the comparative humidities of the two, on account of the effects of snow being omitted in the former. The same excellent authority also adds, that the Rain descends more slowly, and with greater uniformity, in the region to the North of the Alps, that in that to the South. The torrents which burst suddenly from the clouds in that part of Europe, recall, says he, the phenomena of the rainy season in the Tropics. And as a contrast also between our climate and the climates of the Equator, and affording an indirect confirmation of the decrease of Rain with the increase of the latitude, we may add the remark of Malte-Brun, that while here the drops of Rain are only a few lines in diameter, in the torrid zone they reach sometimes almost to an inch.

Difference also in the character of its descent.

Probability that line of maximum Rain will be found North of the Equator.

(552.) It is not impossible but future observations may prove that the greatest amount of Rain is not found at the Equator itself; and as the land appears to influence so considerably all the precipitations of moisture, that the line of maximum Rain will be found in some irregular plane to the North of it.

Relation between tropical rivers and great amount of Rain.

(553.) The magnitudes of what may be called the tropical rivers afford additional evidence of an indirect kind, that the amount of Rain is the greatest in those climes. There must be a relation of some kind or other between the annual fall of Rain and the discharge of rivers.* Mr. Dalton, indeed, deduced from some of his inquiries respecting Rain and evaporation, that in England the Rain and the dew are equivalent to the quantity of water carried off by evaporation and by the rivers; and he infers from it, that as Nature acts upon general laws, it ought to be regarded as the case in every other Country till the contrary is proved. This conditional equation, though deduced from very limited experiments, would seem in a high degree probable. It seems reasonable that the quantity of humidity discharged on a given surface in the shape of Rain or dew, should in some way or other escape from it, either by evaporation or the discharge of rivers; and it is worthy of observation, that Nature seems to have made a provision of some sort for it, in the superior discharge of the rivers we have referred to. We know that the proportional discharge of these rivers, exceeds those of the temperate regions, and hence confirms the indirect evidence we have adverted to.

Dalton's remarks on rivers and Rain of England.

The descent of Rain for same parallel not constant.

(554.) In thus endeavouring to connect the fall of Rain with the latitude, it is by no means intended to infer that the descent is constant through the whole range of the same parallel. In the instance of the Malabar observations before alluded to, the average of which is 123½ inches, we can hardly suppose the same extraordinary fall to prevail throughout the whole of that parallel, in the middle of the Atlantic or of the Pacific, because the average descent

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* The discharges of rivers, particularly those belonging to the tropical regions, are far, however, from being uniform, nor are the superficial extents of their basins by any means constant. In Rennell's Paper on the Ganges and Burrampooter rivers, *Phil. Trans.* 1781, he remarks, that their courses are continually altering, steep banks being formed on the sides which have concave forms, and shelving sides on those which are convex. The outlet of the Jellinghy river has gradually removed three-quarters of a mile further down the Ganges; and, according to two surveys, made of a part of the adjacent bank of the Ganges, at an interval of nine years, the breadth of a mile and a half had been washed away. A mile in ten or twelve years is, Rennel thinks, the usual rate of encroachment, where the current strikes with the greatest force. Some of the Bengal rivers have indeed totally changed their courses. The Cosa river, equal to the Rhine in magnitude, once ran by Purneah, and joined the Ganges opposite Rajemal. Its junction is now forty-five miles higher up. Gour, the ancient Capital of Bengal, once stood on the banks of the Ganges. These are the powers, as Malte-Brun observes, which, set in motion by the hand of Nature herself, and in whose operations ages are accounted as moments, produce some of the great changes which have taken place on the surface of the Globe.

of Rain on the sea, is in general less than on the land, and certainly so in the case we have cited, influenced as the humidity must be by the surrounding mountains, and the woods which more or less cover them. The same principle is moreover confirmed by the well-known fact, that the fall of Rain on the sea-coast, is much more considerable than in places in other respects similarly circumstanced in the interior. According to some authorities, the moisture of the air decreases in a sort of geometrical series in proportion as it is progressively removed from the sea, losing one-third of its moisture in the first four or five hundred miles, a third of that which remains for another interval of the same kind, and so on; but such a ratio must in a great measure be conjectural. We have a comparison by the indefatigable Cotte, made between the sea-coast and the interior, though not confined to the same parallel, and which unquestionably demonstrates the fact. Gottingen, Paris, and Toulouse, not far from the coast, he remarks, have an average fall of Rain amounting to 21.7 inches; whereas at Prague and Buda, situated in the very heart of Europe, and like the former not much elevated, the annual deposit is only 15 inches.

Descent of Rain on sea less than on land.

Fall of Rain on sea-coast more considerable than in interior.

Decrease of moisture assumed by some from sea-coast to the interior.

Comparative examples.

Mountainous Countries most humid.

Causes.

Example of Keswick and Kendal.

Contrast of Puy and Rochelle.

Of Paris, Geneva, and St. Bernard.

(555.) But while in places placed at a considerable distance from the Ocean, and nearly on the same level with it, a decrease in the annual amount of Rain is generally found to exist, an elevation of the land produces a contrary effect; and accordingly mountainous Countries are in all cases found more humid than those comparatively more level. This may, at first, seem contrary to what has been advanced in a former part of the Paper, namely, that the quantity of moisture actually diminishes in some ratio of the ascent; but from the peculiar influences which mountains exercise on the atmosphere surrounding them, the precipitations of moisture and the magnitude of its amount, become much more frequent and considerable, than can possibly be found in the lower regions of the air. The great mountain chains of the globe, indeed, call into activity the real sources of Rain, in their greatest power. To say nothing of the unequal circumstances of humidity in the different strata of the air, the incessant play of the currents generated by the inequalities of the Earth's surface, must incessantly mingle together volumes of unequal temperatures, and thus create, in the lapse of time, a greater amount of Rain than could be produced in the lower regions of the atmosphere, where more uniform laws prevail. In our own Country, Keswick and Kendal, situated among mountains, have annual amounts of Rain respectively 67.5 inches and 54, while many places in the interior of the Country, not much raised above the Ocean, or even on the sea coast itself, have hardly 25. At Puy, situated near the sources of the Loire, the average fall of Rain is 29.5 inches, while 24.5 only fall at the seaport of Rochelle near its mouth;—affording an interesting example of a comparatively small increase of elevation compensating for a great extent of distance from the sea. The annual fall of Rain at Paris also, amounts but to 20 inches, whereas Geneva discloses a mean result of 42.6 inches; and the Great St. Bernard,* the highest Meteorological station in Europe, has an annual fall of no less than 63.13 inches. If we take also the mean result for Toulon, Marseilles, Aix, Montpellier, Arles, Nismes, Cavaillon, and Avignon, places situated between the parallels of 43° and 44° North, and but little raised above the sea, and compare it with a similar mean derived from Orange, Viviers, Lyons, Villefranche, Bourg, and Geneva, found between the parallels of 44° and 46° North, but situated on higher ground, we shall find the same truth confirmed, the first mean amounting but to 22.6 inches, and the latter to 34.3 inches. So also in a series of places to the North of the Alps; *viz.* Carlsruhe, Manheim, Stuttgard, Wurtzburg, Augsburg, and Regensburg, the mean amount of Rain is 25.1 inches; whereas for Zurich, Bern, Lausanne, Peissenberg, and Tegernsee, raised much higher above the sea, the annual average is 40 inches. If again we descend into the Lombardo-Venetian plains, near the Apennines, the mean of eight places gives 29.5 inches; but in the central plain of Lombardy, the average of seven places is raised to 39 inches, and at the very bases of the Alps, and in the lower valleys, the results of twenty places raise the mean to 58.5 inches. In like manner the mean result of observations West of the Lago di Guarda is 42.1 inches, but to the East of the same, in the rising country connected with the Carnic Alps, the average is increased to 62.6 inches.

Toulon, Marseilles, &c. at the level of th sea, compared with Lyons, Geneva, &c. raised above the sea.

Carlsruhe, Manheim, [illegible] North of the Alp compared with Zurich, Bern &c. at higher levels.

Lombardc Venetian plains compared wit central plain of Lombard and with places at the bases the Alps.

Country West of Lago di Guarda comparec with country of Carnic Alps.

As examples of a single year, where the elevations of the places are known, we may give the following:

Places.	Heights above the Sea.	Quantity of Rain in a single Year.
Venice.	zero	31.8 inches.
Verona.	232 feet.	35.0
Udina.	359	64.7
Tolmezzo	1535	109.2

Examples a single year of effects of altitude.

More Ra at bottom a mounta than at t

Dr. Hebe den's dis covery o excess o Rain at lower lev

His expe ment wi three gauges different heights, a single year.

(556.) But, although more Rain falls in mountainous Countries than in Countries of the plain, it is nevertheless an undoubted fact, that the depth of Rain is greater at the bottom of a mountain than at the top, and generally, that a greater quantity falls close to the ground, than at any height above it. Dr. Heberden was the first to remark this phenomenon, by comparing the results of two Rain-gauges at different levels about a mile from each other, the Rain in one of them constantly exceeding the Rain in the other, not only in the average results of a month, but almost every time it rained. Desirous of tracing the anomaly to its source, he had three gauges constructed precisely similar, and one of them placed on the square part of the roof of Westminster Abbey, and at such a distance from the Western towers as to be but little influenced by them. Another was fixed on the top of a house, considerably lower than the first, and a third on the ground in a garden belonging to the house. A year's observations gave the following results:

Gauge on the roof of the Abbey.... 12.099 inches.
Ditto on the top of the house 18.139
Ditto on the ground............. 22.608

This has since been confirmed in a variety of forms by many observers. The best series of observations, however, are those of the Observatory of Paris, under the direction of the able and indefatigable Arago, one of the rain-gauges being in the court of the Observatory, and

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* Meteorological observations on high mountains were first suggested by the celebrated Pictet, and their great advantages are unquestionable. The Monks of St. Bernard have thus a rare opportunity of adding to our knowledge of the atmosphere. We were highly gratified to hear of the kind and hospitable reception which the Members of the Society of Natural History of Geneva received at their hands, during the meeting lately held in that lofty region for various Philosophical purposes. M. de la Rive, the successor of Pictet, has published a very interesting account of it.

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the other on the terrace of that noble building, 28 metres higher. The mean of twelve years gives the following results for the two positions; *viz.*

Observations at Paris for several years.

	Centimetres.
For the terrace of the Observatory	50.471
And for the court of the Observatory	56.374

Same law also to be traced in the several months.

(557.) The law appears to hold good, not only in the mean results for a series of years, but also for the different months, as may be seen in the following Table, the maximum for each situation being in July, but the minimum of the terrace in November, and of the court in February.

TABLE CXIX.

Months.	Mean Amount of Rain for the several Months of the Years 1826, 1827, 1828, and 1829, on the Terrace of the Observatory at Paris in centimetres.	Mean Amount of Rain for the several Months of the Years 1826, 1827, 1828, and 1829, in the Court of the Observatory at Paris in centimetres, the difference of level of the two Gauges being 28 metres, or nearly 92 feet.
January ..	3.571	3.869
February.	3.264	3.694
March ...	3.978	4.592
April	4.927	5.484
May.....	5.596	6.152
June	3.601	3.797
July.....	7.164	7.361
August ..	4.341	4.706
September	5.087	5.329
October ..	3.590	4.035
November	3.034	3.744
December	3.286	3.849

Mr. Howard's observations for separate days.

(558.) The same law may likewise be traced in individual observations, as the next Table illustrates, and which is due to Mr. Howard.

TABLE CXX.

1811. Month.	Wind.	Rain in the upper Gauges 43 feet above the lower.	Rain in the lower Gauge.	Remarks.
Oct. 24	Var.	.05	.08	Misty Rain about mid-day, little wind veering from S.W. to E.
26	Var.	.45	.50	Showers chiefly by night.
27	S. E.	.10	.11	Rain by night.
28	Var.	.44	.44	Clear A. M. with dew. Nimbi. Vane S.E. P.M. A heavy shower to S. Wind veered by S. to N W. then much cloud and Rain.
29	S. W.	.18	.18	Showers.
30	Var.	.08	.14	Three currents in the air. The highest and most considerable mass of clouds moved from the W., and intermediate portion from S., and the wind below fresh at E.
31	W.	.13	.14	Rain by night.
Nov. 1	S. W.	.05	.11	Much cloud with a fresh breeze.
2	S. W.	.06	.14	Cloudy, much wind, stormy night.
3	S. S. W.	.06	.08	Rain by night.
5	S. W.	.09	.25	Stormy A. M. Wet P. M.
6	S. W.	.31	.50	Showery day. Cirrostratus evening. Wet night.
7	N. E.	.06	.07	Rain by Night.
8	S.	.16	.19	Cloudy, drizzling.
9	Var.	.29	.34	
10	S. W.	.19	.21	
11	N. W.	.01	.03	Windy night. Nimbus at sunset.
12	N. W.	.11	.22	Windy night.
		2.82 in.	3.73 in.	

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Remarks on these results.

Rare exceptions to the law explained.

(559.) In two of the results contained in the preceding Table, *viz.* those on the 28th and 29th of October, it will be perceived, that an equality was found in the upper and lower gauges, but in all the others, the excess was found in the lower gauge. There are instances, however, exceptions to the law now under consideration, in which the upper gauge gains the most, but they are very rare. According to Howard, this will be found to be the case, when the source of Rain is high, and the lower air so dry, that the evaporating power exercising its influence on each drop, must occasion a diminution in the amount of Rain. The cause here assigned must, however, be received with caution, as Philosophers are by no means agreed on the point; and with a similar limitation must the solutions that have been offered of the excess in the lower gauge. Arago,—and he is without doubt a very great authority, remarks, that the supposition advanced by some, of the descending streams of moisture reaching the Earth in parallel directions less removed from the perpendicular, on account of the diminished action of the wind, is far from satisfactory. The idea that the drops of Rain augment in magnitude, by appropriating to themselves some of the humidity belonging to the atmospheric strata comprised between the two rain-gauges, he holds to be fallacious also, and to this it has been likewise objected, that the difference is equally found, when the hygrometer, during Rain, does not mark saturation. Boisgiraud, indeed, accounts for this latter difficulty by observing, that the Rain is generally sufficiently cold, relatively to the atmosphere, to cause a precipitation of vapour from the surface of each atmospheric stratum, and thus to augment the quantity of sensible humidity, even when the hygrometer is far removed from the limit of perfect saturation. And in the same way he explains, how it sometimes happens, that the air is not saturated after a shower of a long continuance. Mr. Gough has remarked, that the quantity of Rain at different heights appears to him to be nearly as the height of the plane of congelation above the gauge.

Philosophers not agreed on cause of this, or of the increase at the lower level.

Remarks on the supposed causes.

Inquiry concerning Rain formed between different heights.

(560.) It appears from the last Table, that about one-fourth of the Rain which fell during the term of observation, was formed within 43 feet of the Earth's surface; and it appears also, that this quantity is subject to very great diversity. In the next Table we have given the monthly differences between the results of the higher and lower gauges for the Paris observations for the years 1826, 1827, 1828, and 1829, and in which it may be remarked that the greatest discordances exist.

TABLE CXXI.

Differences in Centimetres between Results of higher and lower Gauges for the Years

	1826.	1827.	1828.	1829.
January ...	.120	.375	.525	.170
February ..	.585	.300	.595	.240
March.....	.285	1.207	.790	.174
April......	.620	.835	.280	.490
May	.430	1.575	.210	.010
June	.070	.110	.425	.180
July	.255	.190	.205	.140
August....	.384	.130	.600	.345
September .	.305	.235	.130	.495
October ...	.525	.745	.050	.460
November .	.865	.565	.230	.130
December..	.810	1.220	.190	.030

In the case of May for 1827 and 1829, the quantities actually formed in the vertical space between the two gauges, were in the ratio of 157 to 1, whereas the whole quanties of Rain deposited at the two elevations did but little exceed 5 to 1.

Relation between Rain on the ground, and that formed within some definite height above it.

(561.) In the next Table we have given the actual amounts of Rain deposited at the lower station, and likewise the absolute quantities formed in the vertical space between the two stations. The ratio of these is given in the third column of the Table.

TABLE CXXII.

Years.	Annual Amount of Rain in the Court in centimetres.	Annual Quantity of Rain formed in the vertical space of 28 metres.	Ratio of the two.
1826	47.209	6.254	100 to 13
1827	57.585	7.487	100 to 13
1828	62.765	4.230	100 to 7
1829	58.889	2.914	100 to 5
Mean of the twelve years above [illegible]en.	56.374	5.903	100 to 11

Not constant.

Mr. Howard's attempt to deduce a correction for it.

Not satisfactory.

Howard's corrections for the different months.

(562.) From this Table also it may be inferred, as well as from Table CXXI., that the quantity of Rain actually formed within the range of some constant elevation is exceedingly variable, and that, therefore, very considerable caution is necessary, in endeavouring to deduce the quantity of Rain actually deposited on the ground, from the results afforded by a rain-gauge at any altitude above it. Mr. Howard has attempted, by the aid of Table CXX., to deduce a correction of this sort, and to apply it to the Royal Society register from 1797 to 1806, by increasing the average annual amount in the Society's gauge, which is elevated 75 feet, from 19.355 inches, to 25.577 inches, the quantity thus presumed to fall on the ground. The ratio employed was that of 28 to 37, or 100 to 132, making the mean increment of Rain 32 for an altitude of 75 feet; whereas the average increment deduced from the Paris observations, and for a greater difference of altitude, amounted only to 11. Mr. Howard's observations, indeed, were too limited in this respect to afford a correct ratio; and it may be remarked respecting his comparison of the average Rain for each month, that while those deduced from the Royal Society's gauge for the period between 1797 and 1806, were confined to a constant altitude of 75 feet, those of his own from 1807 to 1816, were many of them 43 feet above the ground and uncorrected, and the rest on a common level with it. In addition to this, it is hardly proper to compare together observations made in different localities, unless they possess some principle in common, in the present case, either elevation or time. Mr. Howard has, however, constructed a Table of monthly amounts of Rain, corrected for the surface of the ground, in which the rate of allowance is made to increase from 0.05 of an inch in July, to 0.50 in January, and decreasing again through the remaining months in like proportion; the rate of gradation being 0.10 in Spring and Autumn, and 0.05 in Summer and Winter. He remarks, "that the deficiency in the Rain collected at the higher level, from whatever cause or causes proceeding, is very small in the midst of Summer, and increases as we recede in either direction towards Winter. In the former season, the showers fall mostly from elevated clouds, and the lower atmosphere is generally clear of that misty precipitation, which, in the Winter months, must contribute something considerable towards the product at the ground." Mr. Dalton found that a gauge fifty yards high, afforded in Summer two-thirds, and in Winter one-half as much as a gauge on the level of the ground.

Mr. Dalton's relation of t gauges f different seasons.

Mode of correcting rain-gau for differ heights a desiden tum.

(563.) A method, therefore, by which the results of a rain-gauge fixed at a given elevation, can be reduced to what they would have been, had the gauge been entirely on a level with the ground, is still a desideratum. It must, with very few exceptions, be at all times an increment, but one of a most variable kind, subject to great aberrations in the same locality, and differing also with different localities. The Paris observations are the only ones yet known to us where the observations are registered on a systematic plan; and we may hope to receive from the hands of their distinguished observer, when time shall have enabled him to extend them, the element we so much desire, at least for the locality of Paris. In the mean time we may remark, with what very great caution the results of Rain published in our different Journals ought to be received.

This phe menon of Rain the reverse of that of e poration different heights.

(564.) The phenomenon discovered by Dr. Heberden is, therefore, entirely the reverse of the principle which guides evaporation at different heights. The results of the latter are increased by elevating the surface producing the vapour, but the amount of Rain is almost universally diminished.

Rain not precipita with uni formity

In some gions co fined to p ticular p riods.

In other distribut over a w year.

Example Bombay Opposite periods Malabar and Cor mandel coasts.

Less Ra in first than las months the year.

(565.) The amount of Rain in any parallel, although presenting an average result for some definite period, as a year, is nevertheless not precipitated with uniformity during that time. In some regions the Rains are confined to particular periods, descending almost incessantly with very great violence; whilst in others, they may be said to be distributed over the whole year, exhibiting, however, in its two general divisions of the first and last six months, some considerable excess in the latter. The great amount of Rain that falls at Bombay, descends in June, July, August, September, and October, very little appearing in the other months; whereas on the opposite, or Coromandel coast, such are the peculiar effects of the mountain chain of the Ghauts, the wet and dry seasons occur at opposite periods of the year. Thus the seasons of excessive condensation, and those distinguished for serene and cloudless weather, succeed alternately on either side of the great peninsula of India. But if we advance into the more temperate regions of the Earth, we shall arrive at a different arrangement of things. In every place we shall find Rain precipitated during each month of the year, and at a great many an excess of quantity in the last six months of the year. This last truth may be confirmed by referring to the following Table, the mean of the whole giving a relation of 10 to 14. We perceive even from Liverpool and Lancaster, that the results for the first six months being denoted by 10, those for the remaining months require the proportional number 16.

TABLE CXXIII.

Mean Results of the Quantities of Rain falling the first and last Six Months of the Year at different Places.

Name of Place.	Number of Years' Observations.	Rain first Six Months of the Year in inches.	Rain last Six Months of the Year in inches.	Ratio of the Results for the Two Periods.
Manchester	33	14.383	21.757	10 to 15
Liverpool .	18	13.040	21.081	10 to 16
Chatsworth	16	11.652	16.012	10 to 14
Lancaster .	20	15.361	24.353	10 to 16
Kendal . . .	25	22.764	31.180	10 to 14
Dumfries. .	16	15.655	21.264	10 to 14
Glasgow . .	17	8.483	12.848	10 to 15
London . . .	40	8.539	12.147	10 to 14
Paris	15	8.845	11.031	10 to 12
Viviers . . .	40	15.223	20.989	10 to 14
Mean of all Places.		13.245	19.068	10 to 14

Mr. Dalton's explanation of it.

(566.) With his usual ingenuity, Mr. Dalton has endeavoured to account for the excess in question. In the month of January, he says, the vapour actually contained in the air, amounts to about three inches of water, whereas, in July, it is seven inches; the atmosphere containing thus in the latter month, four inches of water more than in the former. Hence supposing the mixture of the aerial currents in both the intervening periods to be the same, the rain ought to be four inches less in the former part of the year than in the latter, producing a difference of eight inches in the whole, and which for Manchester, the residence of that distinguished man, deviates not very widely from the truth.

Amounts for rainy months at Bombay.

(567.) Of the quantities falling during the successive months, the results are necessarily very variable. The means of twelve years' observations for Bombay afford the following results:

June	24.00 inches
July.	23.95
August.	18.87
September	14.06
October	1.26

the greatest being found in June and July, and declining to a very small amount in October. But in the temperate regions, the precipitations will not only be found much diminished in amount, but their arrangement very different also. A few results are thrown into the next Table.

Rain for different months in temperate Regions.

TABLE CXXIV.

Months.	Dalton's Results for Manchester. Mean of 25 Years in inches.	Howard's Results for London. Mean from 1797 to 1806, in inches.*	Howard's Results for London. Mean from 1807 to 1816, in inches.*	Howard's Results for London. Mean from 1797 to 1816, in inches.*	Mr. Daniell's Results for London. Mean of 3 Years, in inches.	Mr. Giddy's Results for Penzance. Mean of 7 Years, in inches.	Mr. Adie's Results for Edinburgh. Mean of 7 Years in inches.
January . . .	2.258	2.011	1.907	1.959	1.483	3.832	1.59
February . .	2.507	1.320	1.643	1.482	0.746	3.257	1.40
March	2.112	1.057	1.542	1.299	1.440	3.876	1.60
April	1.915	1.666	1.719	1.692	1.786	1.819	2.04
May.	2.698	1.608	2.036	1.822	1.858	3.064	1.71
June	2.206	1.876	1.964	1.920	1.830	2.145	1.62
July.	3.400	2.683	2.592	2.637	2.516	2.963	3.13
August. . . .	3.307	2.117	2.134	2.125	1.453	3.496	3.86
September .	2.984	2.199	1.644	1.921	2.193	3.437	2.05
October . . .	3.734	2.173	2.872	2.522	2.073	5.614	2.40
November .	3.378	3.360	2.637	2.998	2.400	5.186	2.80
December. .	3.369	2.365	2.489	2.427	2.426	6.011	2.22

Their maximum and minimum results.

From this Table it appears that the maximum result of Rain occurs at Manchester in July; in London, according to Howard's first and third means, in November, but in his second mean, in October. Mr. Daniell finds, however, the maximum in July for the metropolis. At Penzance, the greatest result, according to Mr. Giddy, is in December; and at Edinburgh, by Adie, in August. Of the minimum results, April belongs to Manchester and Penzance; March for all the three periods of Howard; and February for both Daniell and Adie.

Propriety of reducing months to uniform lengths.

(568.) A rigid comparison of the months can only however be made by reducing them to uniform lengths. M. Flaugergues has done this with respect to his long-continued observations at Viviers, by regarding the months as equal to 30 days 10.5 hours, and from which he has deduced the following results, the mean annual quantity of Rain being taken as unity.

Proportional results, the annual Rain being supposed unity.

TABLE CXXV.

Months.	Proportional Results.	Months.	Proportional Results.
January . . .	0.0716	July.	0.0544
February . .	0.0541	August. . . .	0.0679
March	0.0557	September .	0.1236
April	0.0802	October . . .	0.1370
May.	0.0847	November .	0.1250
June	0.0765	December .	0.0693

The maximum amount here belongs to October, and the minimum to February. The month of May, the author of the Table remarks, comes nearest the mean result of forty years for the Rain. In projecting the results graphically, M. Flaugergues observed that the

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* These results were corrected by Howard for the elevation according to the method before explained.

Rain curve had two minima and two maxima, the former corresponding to February and July, and the latter to May and October. It is worthy of remark also how closely the minima approach to each other, and moreover that they belong nearly to the coldest and hottest seasons of the year. The maxima seem somewhat to accord with the mean temperature of the year. By comparing different places, this active observer imagines that the first maximum is the greatest in Countries situated near to the Ocean, and the second in those regions near the basin of the Mediterranean.

Proportional results for the quarters of the year.

(569.) The results deduced by the same observer for the four quarters of the year, taking December, January, and February for Winter, and the remaining months in classes of three for the other seasons, still denoting the whole amount of Rain by unity, are the following:

Winter	0.1937 inches.
Spring	0.2217
Summer	0.2001
Autumn	0.3845

Mr. Howard's absolute results for a like arrangement of the seasons are,

Winter	5.868 inches.
Spring	4.813
Summer	6.682
Autumn	7.441

Comparison of Rain by day and by night.

(570.) On the comparative quantities of Rain falling by day and by night, Howard has remarked that of 45 inches of rain which fell in the space of thirty-one lunar revolutions, a portion of it, amounting to 21.94 inches, had been separated for the day and the night, the former amounting to 8.67 inches, and the latter to 13.27. According to this experiment the rain by day amounts to about two-thirds of that by night, but such a ratio cannot be general. Mr. Daniell has also remarked that a greater amount of Rain falls while the Sun is below, than while it is above the horizon.

Number of rainy days. Least at the Equator. Increase with the latitude.

(571.) The number of rainy days is the least at the Equator, and increases in proportion to the distance from it. According to Cotte, the mean number of rainy days is 78 between the parallels of 12° and 43° North latitude; and that

From 43° to 46° the mean number is	103
46° to 50°	134
50° to 60°	161

Howard's results for rainy days of the months.

(572.) For our own climate, Mr. Howard remarks, that on an average of years, it rains nearly every other day, more or less, and that the proportional number of days on which it rained in the different months are as follows:

TABLE CXXVI.

Months.	Days.	Months.	Days.
January ..	14.4	July	16.1
February ..	15.8	August	16.3
March	12.7	September .	12.3
April	14.0	October ...	16.2
May	15.8	November .	15.0
June	11.8	December .	17.7

Number of rainy days in the year at Viviers increases.

(573.) The mean of forty years' observation at Viviers, gives 98 rainy days in the year; but by dividing this long period into four decades as follows, it is found that the number of rainy days sensibly increases.

Decades.	Rainy Days.
1778—1787	830
1788—1797	947
1798—1807	1062
1808—1817	1082

Remarks on rainy days at same place.

The Tables from which these results have been obtained, inform us also, that the sum of the rainy days of Winter and Spring at this place, is nearly equal to those of Summer and Autumn; and moreover that the number of rainy days during Autumn and Winter, is to the number of rainy days during Summer and Spring, as nine to seven. By projecting also the monthly results for the days of Rain, the resulting curve was found to have two minima and two maxima; the first minimum belonging to February, the first maximum to April, the second minimum to August, and the second maximum to December. An additional remark of Mr. Flaugergues is also worth recording, that during the forty years of observation, the days of the year on which it has rained the oftenest are October 31st, on which it rained twenty-three times, and Nov. 4th twenty-one times.

Mr.Giddy results for rainy day &c. for Penzance

Mr. Giddy's observations for Penzance contain, however, the most minute information on this subject, and which we have therefore thrown into the next Table. We ardently hope that he may continue them.

TABLE CXXVII.

Months.	Partial Showers.	Showery Days.	Hail Showers.	Snow Showers.	Snowy Days.	Misty Days.	Partial Rain.	Rainy Days.	Number of Days.	Wet Days.	Dry Days.
January ...	61	23	23	20	7	32	93	76	651	335	316
February ..	52	22	25	11	0	33	104	65	593	312	281
March.....	67	14	25	8	0	16	98	51	651	279	372
April......	68	18	27	0	0	15	64	35	630	227	403
May	72	11	7	0	0	21	125	37	651	273	378
June......	70	6	5	0	0	14	86	16	630	197	433
July	65	10	1	0	0	30	98	40	651	244	407
August	88	14	0	0	0	22	110	33	651	267	384
September .	86	16	5	0	0	13	97	34	630	251	379
October ...	79	38	17	1	0	16	100	70	651	321	330
November .	86	30	22	3	0	26	107	82	630	356	274
December..	84	35	43	13	0	16	100	92	651	383	268
	878	237	200	56	7	254	1182	631	7670	3445	4225

(574.) Mr. Howard remarks that about one year in five may be said to be subject to a dry extreme, and one in ten to a wet.

Relation of particular winds and rain. Howard's results, for London.

(575.) There is a connection of some kind between particular winds and the amount of Rain in most localities. Some winds are proverbially wet, and others distinguished as dry. According to Mr. Howard, a wind between North and East, in London, is connected with our driest season, about the vernal equinox; and a wind between South and West, with the wet season following the autumnal. The following are his results for ten years.

TABLE CXXVIII.

Years.	N.—E.	E.—S.	S.—W.	W.—N.	Var.	Annual Amount of Rain in inches corrected for the Altitude.
	Days.	Days.	Days.	Days.	Days.	
1807	61	34	113	114	43	20.14
1808	82	38	108	103	35	23.24
1809	68	50	123	91	33	25.28
1810	81	72	78	83	41	28.07
1811	58	59	119	93	36	24.64
1812	82	66	93	91	34	27.24
1813	76	53	92	124	20	23.56
1814	96	65	91	96	17	26.07
1815	68	36	121	107	33	21.20
1816	64	66	106	102	28	32.37
Means..	74	54	105	100	32	25.18

Remarks on them.

This Table presents some relations between the winds and the annual amounts of Rain. In the driest year of the whole, observes Mr. Howard, *viz.* 1807, the class N.—E. is nearly double the class of E.—S.; and in 1815, the next distinguished for its dryness, a similar relation prevails. In 1808, which is the next in the order of humidity, the former is rather more than double the latter.

In 1816, on the contrary, being the wettest year, the class of E.—S. winds exceeds those of N.—E.; in 1814, it has two-thirds the amount of the latter; in 1812, three-fourths; and in 1810, the remaining wet year, the amount approaches to within a ninth of the N.—E. And with regard to the Westerly winds, the class W.—N. falls off gradually during the three years following 1807, while the annual Rain augments from year to year; and in four of the remaining years, its number is above the average in the dry years, and below it in the wet ones.

Mr. Giddy's results for Penzance.

(576.) Penzance is a place remarkable for the diversity of its individual results, as regards the relations of the winds to Rain, and its peculiar locality would seem to account for it. The County of Cornwall diminishing from the line of its junction with Devon, leaves, at last, Penzance in a locality which may be almost said to be surrounded by the sea. On the South, the deep indentation of Mount's Bay carries into it, without any opposition, all the humidity that the long expanse of water which stretches from its shores can afford; and on the other points, the land can produce but little effect in diminishing the humidity of the air. The atmosphere, however, which rolls from the Western Atlantic on the bold promontory of the Land's End, must necessarily be higher charged with moisture, than that which, coming from the Continent of Europe, may have its humidity in some degree increased by the waters of the English Channel. Accordingly we shall find, by omitting the very rare cases appertaining to the Northerly and Southerly winds in the next Table, that the Rain belonging to the winds of a decidedly Westerly character, exceeds that of the Easterly winds, in a ratio of nearly three to one; the amount of rain for the former winds during the seven years' observations being 216.6 inches and the latter 77.4 inches.

Comparison of Easterly and Westerly winds.

TABLE CXXIX.

Years.	January.		February.		March.		April.		May.		June.	
1821	2.900	N. E.	0.520	E.	4.205	W.	2.300	N. W.	3.385	W.	1.560	S. E.
1822	2.425	N. W.	2.440	S. W.	2.800	S. W.	2.380	N.	1.340	E.	2.240	S. E.
1823	8.625	S. E.	6.965	S. W.	3.205	S. W.	1.980	N. E.	2.770	S. W.	1.940	W.
1824	2.005	N. E.	3.280	W.	5.740	N. W.	2.600	S. E.	3.955	N. E.	4.660	N. E.
1825	3.375	W.	2.700	W.	3.610	N. E.	1.005	N. E.	4.085	S.	1.800	N. E.
1826	3.075	S. E.	5.295	S. W.	2.310	N. E.	1.110	N. W.	0.600	N. E.	0.660	S. E.
1827	4.420	W.	1.600	E.	5.265	W.	1.360	W.	5.315	W.	2.160	N. W.

Years.	July.		August.		September.		October.		November.		December.	
1821	1.660	W.	4.470	S. E.	4.520	S. W.	5.770	S. W.	5.170	S. W.	9.500	S. W.
1822	9.070	W.	2.200	W.	1.865	S. E.	5.315	S.	7.255	S. W.	2.545	E.
1823	3.030	W.	7·085	W.	3.645	W.	8.210	W.	3.705	E.	6.295	W.
1824	3.180	S. W.	2.600	W.	4.165	S. E.	5.965	N. W.	6.910	N. W.	6.470	W.
1825	0.310	S. E.	3.140	N. W.	2.730	S.	5.090	W.	5.820	N. W.	5.285	N. W.
1826	1.240	S. W.	2.115	W.	4.315	S. E.	2.840	N. W.	4.280	N. W.	4.400	N.
1827	2.250	N. W.	2.865	N. E.	2.820	N. W.	6.105	S. E.	3.165	W.	7.580	W.

M. Binder's results for Giengen.

(577.) In the next Table we have the results observed by M. Binder, at Giengen in Wirtemberg, during six years, the numbers indicating the cubic inches of Rain falling during each year, on a square Paris foot, under the influence of the winds indicated.

TABLE CXXX.

Winds.	1823.	1824.	1825.	1826.	1827.	1828.	Amount of the six years.	Proportion for 1000 cubic inches.
N.	60	344	118	53	141	46	762	33.3
N.E.	164	196	119	145	249	47	920	40.2
E.	97	172	52	13	68	70	472	20.7
S.E.	0	15	47	78	62	29	232	10.1
S.	235	230	146	131	226	87	1055	46.1
S.W.	697	1171	885	386	1275	892	5300	231.7
W.	2058	2310	1215	1349	2109	1848	10888	476.0
N.W.	319	778	375	541	924	307	3244	141.8

The Westerly wind presents here the maximum of Rain for the six years, and the next in amount to it is the South-West. The least amounts of Rain are those of the South-East and East winds. The mean direction of the winds producing the greatest quantity of Rain, will thus be for Giengen 85° 23′, or a Westerly wind having a deviation of 4° 37′ towards the South-West.

On the extent of Rain.

(578.) It would be an interesting inquiry could we determine the extent of Rain at a given time. Every shower must have its boundaries with respect to the surface which it covers, but there seems no method by which we can discover them. The dimensions of our Island are but small, and doubtless there are times when the Rain covers a much larger space. Mr. Howard has recorded the remark that the Rain of the 4th of October, 1813, having put a period to a fair season of some weeks' continuance, he availed himself of a journey made immediately after, to endeavour to ascertain how far it had extended. During that day, he says, it rained incessantly the whole distance from London to York, as likewise further North quite to the Tyne, and across the Island from Cheshire to Northumberland. It having been, he adds, a very wet day on the South coast, there can be no doubt that the whole of England, at least, was on this occasion irrigated at once, by the introduction of a current from the Atlantic, which mingling with the South-Easterly breeze that before prevailed, produced the great deposition of water which then took place.

Howard's remarks.

Limits of showers.

(579.) The observer may, however, sometimes clearly trace the limits of showers. Mr. Howard mentions that in travelling at different times between London and Folkstone, in the month of July 1812, the showers seemed to avoid in great measure the high chalky tracts, and to follow the course of the rivers and moist valleys. Sometimes, he says, the reverse distribution takes place. In his remarks on the great drought which prevailed for some time in England in August and September 1815, he observes that for three weeks of the time it rained almost every day in Wales. So also in 1816, while the middle of Europe was suffering from excessive wet,—all the country from the sources of the Rhine among the Alps, to its embouchure in the German Ocean, and through a space three times as broad from East to West, being submerged in water, dikes being broken, bridges blown up, the crops spoiled or carried off by torrents, and the vintage ruined by the want of the sun to bring out and ripen the fruit; the North for a time, and to a certain extent, was parched with drought; and public prayers appear to have been ordered about the same time at Dantzig and Riga for Rain, and at Paris for sunshine.

During great drought in England, it rained for three weeks in Wales

Opposite states of North and South of Europe in the same respect.

Excessive Rains.

(580.) There are many instances on record of excessive rains for the parallels on which they fall. This happens two ways, either by a general augmentation of the Rain for the month or year, or by great precipitations in a shorter time. Thus, in the latter half of June and the former half of July 1810, Mr. Howard mentions the amount of Rain to be 5.13 inches, whereas the general average for the time could hardly have exceeded 2.3 inches; and many other examples are recorded in his Meteorological Tables. At Kendal, in 1782, there fell 83.5 inches of Rain, the average result being 54 inches. And with respect to sudden precipitations of Rain, Howard has an instance of 0.89 inches falling between four and half past seven A. M. on the 8th of August. On the 8th of May also, an inch and a half fell in twelve hours. At Perth, on the 3d of August, 1829, four-fifths of an inch descended in half an hour. But the most extraordinary examples are those which occurred on the Continent of Europe in 1827, and recorded in the XXXVIth volume of the *Annales de Chimie*. Arago remarks of them, that the annals of Meteorology offer nothing so remarkable, either in France or in any other Country, not excepting the Equatorial regions. On the 20th of May there fell at Geneva in the short interval of three hours, 6.4 inches of water. At Montpellier there descended in five days, from the 23d to the 27th of September inclusive, 16.7 inches of Rain; and at the Chemical Manufactory of M. Bérard, near the same city, the amount of precipitation in forty-eight hours, from the 24th to the 26th of the month last quoted, the rain was 12.6 inches. Again at Joyeuse, in the Department of Ardêche, according to the register of M. Tardy de la Brossy, the maximum of Rain in a single day in the course of twenty-three years, was found on the 9th of August, 1807, and amounted to what then appeared the enormous quantity of 9.868 inches; but on the 9th of October, 1827, in the space of twenty-two hours only, there descended at the same place 31.173 inches of Rain. We record the original words of Arago for the entire satisfaction of our readers.

Examples for months of a year.

For short periods.

Prodigious falls on the Continent in 1827, exceeding even the Tropical Rains.

Le 9 *Octobre*, 1827, *dans l'intervalle de vingt-deux heures, il est tombé, dans la même ville de Joyeuse*, 29 *pouces* 3 *lignes d'eau:* (vingt-neuf pouces trois lignes:) *j'écris*, continues that distinguished man, *le résultat en toutes lettres afin qu'on ne croie pas à une faute d'impression.*

In eleven days of the same month of October, there likewise descended at the same place 38.37 inches of Rain, a quantity double of that which usually falls in Paris in a year. At Bombay it was noticed as a remarkable occurrence in 1826, that 32 inches of Rain fell in the twelve first days of the rainy season; whereas this quantity but little exceeds that which fell at Joyeuse in a single day. The maximum results of Rain in twenty-four hours on the coast of Malabar for several years, together with the commencement of the Monsoons, are given in the next Table.

Maximum results of Rain in twenty-four hours, during Monsoons on Malabar coast.

TABLE CXXXI.

Years.	Maximum Quantities of Water in 24 hours, in inches.	Commencement of the Monsoons.
1810	4.80	May 20th.
1811	4.50	May 31st.
1812	4.85	May 31st.
1813	4.60	May 27th.
1814	3.90	June 15th.
1815	5.40	May 27th.
1816	3.75	June 18th.
1817	4.55	May 26th.
1818	6.63	June 5th.
1819	7.60	May 9th.
1820	5.38	May 26th.
1821	4.66	June 16th.
1822	4.89	June 2d.
1823	6.46	June 6th.

The discordance between the greatest of these results and that for Joyeuse is most remarkable. Captain Roussin relates that 151 inches of Rain fell at Cayenne in the month of February.

Diversities of Rain in localities not far from each other. Examples.

(581.) It may be proper also to advert to the phenomenon of the diversity of Rain in localities not far distant from each other. In the district of Doombera in Ceylon, one side of a lofty mountain ridge is covered with clouds and mists, and drenched with Rains, at a time when the other is parched with drought, and scorched by an unclouded sun. The little town of Cumanacoa, also, is about 100 toises above the level of the sea, and seven leagues from the port of Cumana. At the latter place it seldom or never rains, while at the former there is a regular rainy season of seven months' duration. Rain again falls but seldom on the Western shores of any of the Sandwich Islands, though showers are frequent on the Eastern or windward sides, and on the mountains they occur almost daily. Between Bombay and the Southern part of the Malabar coast, places not five hundred miles from each other, very great differences are found to prevail, both in individual years and in the amounts of the annual means. In the following Table we have recorded a few results of each.

Great differences for Bombay and Southern part of Malabar coast.

TABLE CXXXII.

Years.	Amount of Rain at Bombay in inches.	Amount of Rain on the Coast of Malabar in inches.
1817	103.79	136.70
1818	81.14	169.19
1819	77.10	135.47
1820	77.34	147.18
1821	82.99	98.44
1822	112.61	145.60
1813	61.70	121.67
Means	85.24	136.32

Here the average annual amount of Rain differs sixty per cent. within so small a Geographical interval; and in two of the years, *viz.* 1818 and 1823, it is even doubled, and in the other years the differences are enormously large.

Inquiry respecting Paris and Versailles.

There is a popular belief also that it rains in Versailles much more considerably than it does at Paris, although the two places are so near each other. Arago, however, with his usual caution, remarks, that before we endeavour to explain why such a difference exists, it would be first proper to inquire if it really exists at all. He gives us the results of two years' observations for each place, and although it would seem to be completely verified in the first, yet it is directly contradicted in the second. More observations therefore are necessary to decide the question. This is an example also to prove the necessity of inquiring into all Meteorological conclusions which have no other foundation than popular belief.

Years.	Rain at Paris in centimetres.	Rain at Versailles in centimetres.
1825	51.93	57.65
1826	47.21	46.15.

Rain constant at Paris, but increasing at Viviers, although many forests have been cut down.

(582.) It is a curious phenomenon, and worthy the attention of the active Meteorologist, that while the quantity of Rain seems constant in some localities, it appears not to be so in others. At Paris, Arago observes that it has not varied in any sensible degree for 130 years. M. Flaugergues found however on the contrary that the Rain has augmented at Viviers, although since his observations, commenced in 1778, most of the forests which covered the Department of Ardêche have been destroyed. The following are his results.

TABLE CXXXIII.

Decades of Years.	Quantity of Rain fallen during each Decade in French Measure.			Mean annual Quantity of Rain in French Measure.	
	Feet.	in.	lines.	In.	lines.
1778—1787	25	11	2	31	1 10/30
1788—1797	27	8	2 2/3	33	2 20/30
1798—1807	28	5	11 2/3	34	2 11/30
1808—1817	31	1	11 2/3	37	4 23/30

Increasing also at Milan.

(583.) It appears also from observations made at Milan, that the Rain has been constantly augmenting there, from 1764, to the epoch at which the calculations were published by Carlini in the *Ephémérides de Milan* for 1816, or as given in the succeeding Table.

TABLE CXXXIV.

Period.	Mean Amount of Rain.	
	In.	lines.
From 1764 to 1781	32	11
1773 to 1790	32	17
1782 to 1799	34	11
1791 to 1808	35	18
1800 to 1814	38	9

The same conclusion is confirmed by M. de Césaris, whose results are as follows:

Mean quantity of Rain from 1764 to 1790 = 91 centimetres :
Mean quantity of Rain from 1791 to 1817 = 101 centimetres :

Confirmed by M. de Césaris.

His cause for it.

Arago's doubts.

Wide aberrations.

and which he accounts for by the numberless channels from year to year formed, for the purposes of irrigation, in the plains of Lombardy. Arago, however, without denying the cause assigned by the Milanese Astronomer for the increase, thinks it may be necessary to inquire if a period of twenty-seven years is sufficient to afford a general result,* in order to be freed from the effects of accidental variations; and he grounds his opinion on the great discordances existing among the individual results from which the means were deduced. In the first period above adverted to, the mean annual amount of Rain varied from 26 French inches to 47.5 of the same measure; and in the last interval also of twenty-seven years, the annual extremes presented the wide divergence of 24.7 and 58.9 inches of the same scale.

More attention due to this subject.

Effects of woods.

Progressive.

Rain decreasing at Marseilles.

(584.) The whole of the phenomena, however, connected with this branch of our subject, merit a more extended examination; and some attention is due to the fact before adverted to, respecting the destruction of woods. M. Moreau de Jonnes, author of a Prize Essay, proposed by the Philosophical Society of Brussels, on the alterations produced in the physical state of Countries by the destruction of forests, asserts that a progressive diminution of Rain has taken place in the South of France, in consequence of the destruction of mountain woods; and the remark seems confirmed by the following results for Marseilles.

TABLE CXXXV.

Period.	Mean Quantity of Rain in centimetres.	Mean Number of Days of Rain.
From 1772 to 1782	59	57
1795 to 1805	53	54
1806 to 1815	38	55
1815 to 1820	37	—

Arago however regards the different results between Viviers and Marseilles as accidental.

Arago, however, observes, on comparing the Tables of Viviers and Marseilles together, the distance of these places not being very great from each other, that the differences they present ought to be regarded as accidental.

Intensity of diurnal Rain at Viviers not constant.

Intensity in Decades.

(585.) It is a curious remark of Flaugergues, that the intensity of the diurnal Rain is not constant. If we divide, says he, the total quantity of Rain which fell during the forty years' observations, *viz.* 16,312 lines by 3921, the number of rainy days during that time, we shall obtain 4.16 lines, for the mean amount of Rain falling in a day. And if, in a similar manner, we divide the quantities of Rain that fell during each decade, by the number of rainy days in that decade, we shall obtain the mean quantity of Rain which fell during a day in the several intervals assumed. The results are contained in

TABLE CXXXVI.

Decades of Years.	Intensity of the Diurnal Rain in lines.
17[illegible]8—1787	4.499
1788—1797	4.210
1798—1807	3.864
1808—1817	4.148

Here the intensity of the diurnal Rain has diminished during the first three decades, but augmented in the last.

Mean intensity of diurnal Rain.

(586.) In like manner, by dividing the quantities of Rain which fell each successive month by the number of rainy days corresponding to that month, he obtained the mean intensity of diurnal Rain during each successive month, as in

TABLE CXXXVII.

Months.	Intensity of Rain in lines.	Months.	Intensity of Rain in lines.
January....	3.447	July......	3.946
February..	2.912	August....	5.690
March	2.938	September .	6.647
April	3.551	October ...	5.481
May......	4.199	November .	4.641
June......	4.059	December..	2.869

A maxi mum in Septem

Thus the intensity of Rain seems to be the greatest in September, or during that month the greatest quantity of Rain falls in the shortest time. It is during this month, or in October, that the great inundations of the torrent of Escoutay take place.

In Sum a heav shower causes duction temper ture.

In Wi it caus an ele tion.

(587.) In Summer it is generally observed, that a heavy shower of Rain causes a reduction of temperature; but in Winter an increase is found to follow its descent. In the former season the Earth is necessarily heated, and the precipitated vapour coming from a colder region of the sky above it, a portion of the caloric at the surface must pass into the water that has descended, and thus occasion a reduction of sensible heat. Added to this, evaporation must sometimes take place, and thus add to the decrease of temperature. In Winter, on the contrary, so soon as the condensation takes place, the caloric disengaged has a sensible effect on the low temperature of the surface, and produces that augmentation of the sensible heat which is commonly perceived.

Air tr parent fore a of Ra

(588.) Previous to a fall of Rain, the transparency of the air is very great. M. De Luc has investigated this subject in a Paper read before the Helvetic Society of Natural Sciences in July 1825. Rain is sometimes found positively and at other times negatively electrified, and sometimes non-electric.

Relat Rain phase the M

(589.) Meteorologists have likewise connected the phenomena of Rain with the different phases of the Moon, and there is perhaps no remark more common, than that changes from wet to dry, and from dry to wet, generally occur during its changes. Mr. Howard has

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* Twenty-seven years may seem, to the ordinary inquirer, a term sufficiently long to determine an average result. But Arago looks at things widely, and with the comprehensive view of a Philosopher. Where uniform causes prevail, short intervals will enable us to determine a mean; but where the aberrations are great, and they are spread over a long interval of time, a longer period becomes necessary. The future progress of Meteorology may enable us to contemplate this subject of the mean with more accuracy and generality.

Meteorology.

traced this with some success, but it still demands a more extended inquiry. According to him, when the Moon has great South declination, there falls but a moderate quantity of Rain with us; and that while she is crossing the Equator towards these latitudes, our Rain increases. The greatest depth of Rain falls with us in the week in which she has the greatest North declination; and during her return to the South, the Rain becomes reduced to its minimum state. And this holds good in very nearly the same proportions, both in extremely wet and dry seasons.

Relation of Rain to the Moon's declination.

Relation between phases of Moon and number of rainy days.

(590.) There exists also, according to M. Flaugergues, a constant relation between the phases of the Moon and the number of rainy days. From observations made by him, during a period of nineteen years, he obtained the following results.

Table CXXXVIII.

	Phases of the Moon.					
	New Moon.	First Quarter.	Full Moon.	Last Quarter.	Moon in Perigee.	Moon in Apogee.
Number of rainy days coinciding with the days of the Moon's phases....	77	82	79	60	93	78

And he adds, that the number of rainy days which coincide with the days of the Moon's phases, and of the perigee and apogee, follow the same progress as the mean heights of the barometer corresponding to these phases, but in an inverse order. Thus the number of days at new Moon on which it rained, is less than the number on which it rained at full Moon; and the mean height of the barometer on the day of the Moon's conjunction, is, on the contrary, greater than on the day of her opposition. In like manner, the number of rainy days belonging to the first quarter much exceed those of the last quarter, and so conversely the mean height of the barometer is much less in the first quarter than in the last. And lastly, the number of rainy days coinciding with the days on which the Moon was in perigee, is much greater than the days corresponding to her apogee; and so on the contrary, the mean height of the barometer at the former season, is much less than at the latter.

The diminution of the atmospheric pressure, caused by the attraction of the Moon, must be regarded as among the causes that determine the fall of Rain.

(591.) The following Table contains the results of Rain for different places, arranged according to their progressive numerical amount.

Table CXXXIX.*

Names of Places.	Number of Years.	Annual Amount of Rain.
Uleaborg	?	13.5
Petersburgh	?	16.0
Upsal	?	16.7
Mean rain for lat. 60° (Humboldt)		17.0
West Bridgford	?	17.0
Wittenberg	?	17.0
Petersburgh, another result	?	17.2
Lund	?	18.5
Diss, Norfolk	?	18.7
Upminster	?	19.5
Paris	15	19.9
Carlisle	1	20.2
Berlin	?	20.6
London (Dalton)	40	20.7
Widdrington, North	1	21.2
Glasgow	17	21.3
Edinburgh	?	22.0
Dublin	?	22.2
London (Daniell)	3	22.2
South Lambeth	9	22.7
Mean of Toulon, Marseilles, Aix, Montpellier, Arles, Nismes, Cavaillon, and Avignon, between 43° and 44° North, at the level of the sea (Schow)		22.6
Near Oundle, Northampton	14	23.0
Lisle	?	24.0
Lyndon, Rutland	21	24.3
Rochelle	?	24.5
Edinburgh	3	24.5
Utrecht	?	24.7
Haarlem		24.7
Youngsbury, Hertfordshire	5	25.0
Kimbolton	?	25.0
Mean of Carlsruhe, Manheim, Stuttgard, Wurtsburg, Augsburg, and Regensburg (Schow)		25.1
London (Howard)	23	25.2
Norwich	13	25.5
Vallerie, five leagues N. E. of Rochelle	18	25.6
Rochelle, another result	17	25.8
Fyfield, Hampshire	7	25.9
Edinburgh (Adie) another result	7	26.4
Ferriby, Yorkshire	?	26.6
Chichester	?	26.8
Epping	7	27.0
Ulm	?	27.0
Algiers	?	27.0
Barrowby, Yorkshire	6	27.5
Strasburg	20	27.6
Chatsworth	16	27.7
Hague	?	28.4
Delft	?	28.6
Harderwyk	?	28.6
Mean rain for lat. 19° (Humboldt)		29.0
Bristol	3	29.2
Bridgewater	?	29.3
Gordon Castle	?	29.3
Abo	?	29.3
Puy, near the source of the Loire	?	29.5
Lombardo-Venetian plains, near the Apennines, a mean of eight places (Schow)		29.5
Leyden	?	30.2
Madeira	?	31.0
Minehead, Somerset	?	31.3
England, Dalton's mean, taking first a mean of the Counties		31.3

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* The mark ? inserted so often in the above Table, merely denotes the number of years to be unknown, and not that the amounts of rain are *known* to be doubtful, although we cannot place entire confidence in more than a few results of the Table. It will be observed that the means which rest on the respectable authorities of Humboldt and Schow, have not those doubtful marks attached to them; but though the number of years from which they are derived be not known, a high degree of reliance may be placed in them. In one or two instances, the same place has different results assigned to it, the consequence, perhaps, of different localities, or of different modes of reducing the results. What a vast field of inquiry remains to be explored in this interesting branch of our subject, and what unwearied industry and precautions will be necessary to improve it!

TABLE CXXXIX. *continued.*

Names of Places.	Number of Years.	Annual Amount of Rain.
Venice	1	31.8
Mean of sixteen places in Great Britain (*Ency. Britt.*)		32.5
Zurich	?	33.1
Exeter	?	33.2
Liverpool	18	34.1
Mean fall of rain, from lat. 44° to 46°, *viz.* at Orange, Viviers, Lyons, Villefranche, Bourg, and Geneva, (Schow)		34.3
Padua	?	34.5
Cotte's mean of 147 places in Europe		34.7
Verona	1	35.0
Mean of 32 places in Great Britain, mostly rainy, (Dalton)		35.2
Sienna	?	35.2
Viviers	40	36.2
Venice, another result	?	36.1
Manchester	33	36.1
Dumfries	16	36.9
Isle of Man	6	37.0
Selbourne, Hampshire	?	37.2
Dover	5	37.5
Rome	?	39.0
Central plain of Lombardy, mean of seven places, (Schow)		39.0
Lyons	?	39.4
Lancaster	20	39.7
Mean result for Zurich, Bern, Lausanne, Peissenberg, and Tegernsee, (Schow)		40.0
Kirkmichael, Dumfries	?	40.3
Ludgvan	?	41.0
Dordrecht	?	41.0
Townley, Lancashire	15	41.5
Country to the West of the Lago di Guarda, (Schow)		42.1
Geneva	?	42.6
Stockey Muir, near Glasgow	?	42.6
Pisa	?	43.2
Laigs	?	43.5
Penzance	7	44.7
Lancaster	10	45.0
Waith Sutton, Westmoreland	?	46.0
Charlestown	10	50.3
Joyeuse	12	50.9
Garsdale, Westmoreland	3	52.3
Kendal	25	53.9
Fellfoot, Westmoreland	3	55.7
Kendal, another result, (Marshall)	9	56.2
Mean of twenty places in the lower valleys at the very bases of the Alps, (Schow)		58.5
Crawshawbooth, Lancashire	2	60.0
Country to the East of the Lago di Guarda, (Schow)		62.6
Great St. Bernard	?	63.1
Vera Cruz	?	63.8
Udina	1	64.7
Keswick	7	67.5
Mean rain for lat. 19° (Humboldt)		80.0
Calcutta	?	81.0
Bombay	12	82.0
Ceylon	1	84.3
Carfagnano in the Apennines	?	92.0
Equator, (Humboldt)	?	96.0
Adam's Peak, Ceylon	1	100.0
Tolmezzo	1	109.2
Cape Francois	?	120.0
Coast of Malabar	14	123.5
Granada	?	126.0
Leogane, St. Domingo	?	150.0

Snow.

Snow.

(592.) The precipitations of moisture so often resulting from the union of atmospheric volumes of unequal humidity and temperature, cannot, however, at all times descend in the form of Rain. The region of the air in which they take place is subject, like the surface of the Earth itself, to different vicissitudes of temperature; and in the season of Winter, when a diminished radiation causes the atmosphere frequently to sink below the freezing point of water, the particles of moisture must, in some stage or other of their descent, become frozen, and form flakes of Snow, having great diversities of density, and displaying innumerable varieties of the most beautiful forms, and at length reaching the ground in those states, when the temperature necessary for their first formation continues down to the ground.

Density of Snow not constant.

Experiments of M. Quetelet.

(593.) The density of Snow is far from being constant, and M. Quetelet has endeavoured to show that there is a relation between it and the form. By representing by unity the volume of water produced from the melting of a constant mass of Snow, he found the maximum of density to exist when the Snow remained on the ground in one uniform mass, its numerical value being $\frac{1}{2.5}$, at a temperature of 34°.5. The least condition of density varied between $\frac{1}{10}$ and $\frac{1}{12}$, the temperature ranging from 29°.7 to 18°.5, the forms of the Snow being very small stars. Unformed flakes had a density of about $\frac{1}{5.6}$ at a temperature of 33°.1; and fine Snow, having no determinate forms, was found with a density of $\frac{1}{4}$ and $\frac{1}{7.5}$, the temperature varying from 32° to 30°.2.

Beautiful forms of Snow.

(594.) Snow presents the most beautiful variety of forms, and when examined by the microscope is found to be composed of an immense number of separate and transparent crystals of ice. In the Polar regions, where a diminished temperature calls into the highest activity the crystalline power, their variety seems endless; and while a general character pervades the whole, the groupings produced by combination, disclose arrangements uniting at once the most perfect forms of regularity and beauty. Dr. Nettis of Middleburgh, in 1740, was the first to describe some that fell in the intensely cold Winter of that year. They were found to be hard, entire, and pellucid; and some particles received on a pencil, were placed on a plane glass plate, under the object glass of a fine microscope. Great care was taken that the smallest particles might not be dissolved, either by the breath or the warmth of the hand. In one day and night he found twenty or more particles differently formed; and on several other days he enjoyed opportunities of delineating eighty admirable figures of Snow, many of which we have given in the figures comprised from 1 to 29 of plate iii. The size of these varied from $\frac{1}{20}$th to $\frac{1}{3}$th of an inch. Figs. 30, 31, and 32, are examples of anomalous figures of Snow, and of which he observed an almost infinite variety.

Forms.

(595.) We owe, however, to Mr. Scoresby the most exact and accurate delineations of the forms of Snow, which he obtained during his successive Polar voyages. This indefatigable observer did not content himself with mere outline descriptions, but measured the magnitudes of the particles he examined, classified their different modifications, and noted the barometrical and thermometrical conditions of the air, as well as the general aspect of the weather during the time of observation. Mr. Scoresby's varieties are arranged under the five following forms:

Reduced to five general classes.

1. Lamellar.
2. A lamellar or spherical nucleus, with spinous ramifications in different places.
3. Fine spiculæ, or six-sided prisms.
4. Hexagonal pyramids.
5. Spiculæ, having one or both extremities affixed to the centre of a lamellar crystal.

(596.) Of the first of these divisions, the varieties were found to be very numerous, and abundantly formed at all temperatures sufficiently low to call into activity the crystallizing force. Their structure is highly delicate, and very thin and transparent. It may be divided into several distinct species.

(597.) *Stelliform*, having six points radiating from a common centre, with parallel, collateral ramifications in the same plane. This species is represented in fig. 33, and is the most general form met with. It varies in size from the smallest point to about one-third of an inch in diameter. It occurs in the greatest abundance when the temperature approaches the freezing point.

(598.) *Regular hexagon.* This occurs in moderate as well as at the lowest temperatures; but its structure becomes more delicate and thin, and its size is diminished, as the temperature itself is lowered. In some cases it assumes the form of transparent plates, as in fig. 34; whilst in others, figures of the most beautiful regularity are formed within the perimeter, by different white lines. The size of this species is from the smallest visible atom to about one-tenth of an inch in diameter. Some of these forms are delineated in figs. 35, 36, 37, 38, and 39.

(599.) *Aggregation of hexagons.* This beautiful species admits of endless variety, and is formed chiefly at low temperatures. A few are delineated in figs. 40, 41, 42, 43, 44, 45, 46, 47, and 48.

(600.) *Combinations of hexagons with radii or spines and projecting angles.* This species is by far the most numerous, and affords some of the most interesting specimens. Figs. 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, and 67, afford examples of it. The parallel lines in these figures, are not intended as shadings, but actually occurred in the crystals though with this difference, that the lines which appear black in the diagrams, were white in the originals. Figs. 68 and 69 afford examples of crystals having twelve spines, and seem like aberrations from the general law which governs crystallizations of this kind; but as Mr. Scoresby justly observes, they may rather be regarded as accidental varieties, produced probably by the correct application of two similar crystals upon each other.

(601.) Of the second general division, it would be difficult to convey an exact representation by means of a figure. It seems, however, to consist of two or three species, the fundamental figure of which is either of the species before described, and from the lateral and terminal planes of which arise small spines, similar to the collateral ramifications of fig. 53. These spines spring from one or both of the lateral planes or principal surfaces, or from both lateral and terminal planes, maintaining a constant angle of 60° with the plane from which they rise. The diameter of the crystal sometimes exceeds the fourth of an inch, and Mr. Scoresby found it most frequently to form at a temperature of 20° or 25°. In some cases, a spherical nucleus is to be traced, from which spring radii in all directions. In the former, the central figure is transparent, but in the latter consists of a small, rough, white concretion, its diameter seldom reaching a quarter of an inch. The spines or radii are similar in both. This latter species is formed at about the freezing point, and sometimes in temperatures rather lower.

(602.) The third class contains examples of very delicate and crystalline forms, and also of forms quite white and rough. The finest specimens resemble white hair, cut into lengths, not exceeding a quarter of an inch, but so small and clear as not easily to admit of an exact determination of their figure. Another variety, occasionally the third of an inch in length, exhibits a fibrous or prismatic structure. When the temperature is about 28 degrees, the finer specimens occur, and the coarser at about the degree of the freezing point. The latter are very common during fog showers, and appear to be composed of aggregations of the frozen particles of the fog, and to have their origin in the lower parts of the atmosphere.

Fourth class.

(603.) The fourth class seems to be very rare, Mr. Scoresby having observed it but on one occasion. It apparently consisted,—for in a delicate examination of this sort more than one instance is necessary,—of a triangular pyramid, but whether its base was triangular or hexagonal, similar to fig. 67, he could not determine. The pyramids were about the thirtieth of an inch in height, and fell with some other curious figures during a gale of wind from the North. They are represented in figs. 68 and 69.

Singular forms of the last class.

(604.) The last species was seen by Mr. Scoresby only twice. It resembles, he says, a pair of wheels, united by an axle-tree, the wheels consisting of hexagonal or other lamellar crystals, and the axle of a slender prism. Figs. 70 and 72 represent examples of this Snow crystal. Fig. 71 is another, having three laminæ, and two prisms about one-sixth of an inch long; and fig. 73 is an instance of one tabular crystal and a prism. This last and the two former varied from one-thirtieth to one-tenth of an inch in length. The temperature, when the very singular form of fig. 45 occurred, was in one instance 22°, and in the other 20°.

Remarks on magnitudes of illustrative figures.

(605.) The figures we have given to illustrate these curious and very interesting forms, Mr. Scoresby informs us are magnified from 30 to about 400 times. The fractional numbers succeeding each crystal, denote the diameter in parts of an inch. The largest crystal represented was one-third of an inch, and the smallest one-thirty-fifth.

The most perfect figures fall at low temperatures.

Remarks on the varieties of form.

(606.) The figures actually recorded here were all perfect specimens seen by Mr. Scoresby; but many instances occurred during his long investigation of the subject, of mutilated and irregular forms, some wanting two or three radii, and others having radii of different sizes and shapes. At low temperatures, however, the greatest proportion of crystals that fall are probably perfect Geometrical figures. The constant regard to equality, in the form and size of the six radii of the stellates, the minute accuracy of the different parts of the hexagons, the beauty and precision of the internal lines of the compound figures, with the proper arrangement of any attendant ramifications, together with the general completion of the regular figures belonging to such diversified forms, compose one of the most interesting among the many admirable examples with which Crystallography abounds.

Seldom met with in temperate regions.

Snow in Swisserland.

(607.) But these delicate and beautiful forms are principally confined to the Polar regions, and only in very rare instances are some of the less complicated crystals to be met with in the temperate climates of the Earth. In Swisserland, the descent of Snow in crystallized stellar pallets, with feathery filaments arranged along the rays, was regarded in January 1829 as an uncommon phenomenon. M. Huber-Burnand, who particularly watched its descent, gave to it the name of

Varieties.

Polar Snow, from its corresponding to the description given of such, and which name it retained. Five or six inches of it fell in three successive days, and was found to be extremely light, very dry, and without adhesiveness. Instead of presenting a swan like whiteness, it had more the silvery appearance of feathers of the colymbus, in consequence of the high polish of its crystalline facets. When dropped freely into a basin, measured, and then melted, it gave one-forty-fifth its volume of water. On some foggy days, another kind fell, which was called *Elementary Snow*, and was supposed to be formed near the Earth. Its form was that of fine powder, but without any regular crystallized form. The temperature ranged during these formations ten or fifteen degrees below the freezing point.

Experiment of Monge to illustrate the formation of Snow.

(608.) Monge the Geometrician has alluded* to the ordinary crystallization of sal ammoniac in delicate feathery crystals, as affording a beautiful illustration of the formation of Snow. If we fill, says he, a deep glass to which heat has been applied with a saturated solution of sal ammoniac in a warm state, and allow it to cool in a tranquil air, the surface of the Liquid will be covered with very minute crystals. These will sink as soon as they are formed, and descend slowly, on account of their Specific Gravity but little exceeding that of the Liquid. During their descent they will receive other aggregations, and at length reach the bottom of the vessel in large white flakes. The rapid progress of crystallization is entirely owing to the affinity of the particles. The first crystal which descends forms as it were a nucleus for all the other particles which have a tendency to unite to it. But no experiment can do adequate justice to the exact Geometry and delicate mechanism of Nature.

Natural Snow-balls of globular forms.

(609.) There are other crystalline forms of Snow, which however merit attention. Sometimes when a strong wind sweeps over a surface of Snow, portions of it are raised by its power, and passing on with the breeze under a diminished temperature, become crystallized, and by attrition assume globular forms. In some instances their size is so much increased by the continual accession of Snow, as at length entirely to resist the action of the wind, and to remain at rest. An example occurred to Mr. Howard, in January 1814, of several thousands of balls being formed under circumstances of this kind.

Seen by Howard.

By Sherriff, and formed by wind.

(610.) Mr. Sherriff records an instance of balls being found by him, in February 1830, in East Lothian, varying from a foot to a foot and a half in diameter, which had left hollow tracts in the Snow, ranging from East to West, the wind at the same time blowing from the latter quarter. In one village in particular, with a complete exposure to the West, they were exceedingly numerous, and not above a yard and a half from each other.

By Cleveland.

(611.) An example occurred to Professor Cleveland, so late in the year as 1st of April, in North America, of Snow-balls varying in size from one to fifteen inches diameter, the smaller being nearly spherical, and the larger somewhat spheroidal. The larger balls were formed by having been rolled through a considerable distance by the wind, their paths upon the Snow being in general distinctly visible. The smaller balls however, the Professor asserts, were decidedly formed in the atmosphere, as they occurred in woods and small enclosures. The texture of all these balls was homogeneous, being composed of minute prisms of Snow irregularly aggregated. Those observed by Mr. Sherriff were entirely destitute of crystalline forms. In some cases it is said that aggregations of Snow have occurred in decidedly cylindrical forms, hollow at each end to almost the centre; but the accounts that have been published of them do not seem satisfactory.

Smaller balls forme in atmosphere.

Cylindrica forms, hollow at eac end doubtful.

Peculiar character imparted t scenery by Snow.

(612.) After a copious fall of Snow, an attentive observer may find in the scenery, to which it imparts so peculiar a character, much to exercise and delight his mind. "The pensile drifts," says Mr. Howard, "resting on a narrow base, invite contemplation, at the time they may be regarded as just objects of fear." Sometimes when the Sun shines clearly, and the temperature is too low to permit any deposition of moisture, the level surface may be found sprinkled with small polished plates of ice, which refract the light in colours as brilliant and varied as those of dew. At such times, also, there are to be found on the borders of frozen pools, and on small bodies which happen to be fixed in the ice and project from the surface, groups of feathery crystals of a curious and delicate structure. From the moment almost that snow alights on the ground, it begins to undergo certain changes, which usually end in a more solid crystallization than it originally possessed. The peculiar adhesive quality of Snow at particular times, results from its needly crystalline texture, aided by a degree of attendant moisture, which afterwards freezes in the mass. Snow sometimes exhibits beautiful blue and pink shades at sunset.

Surface of Snow sprinkled with small polished plates of ice.

Snow changes soon as it reaches th ground.

Cause of adhesive quality of Snow.

Different colours o Snow.

(613.) Snow has been seen in the Polar regions of red, orange, and salmon colour. This occurs both on the fixed and floating ice, and appears in some cases to result from vegetable, and in others from animal matter, suspended in the sea, and deposited upon the ice around.

Luminou Snow storms.

(614.) Snow storms sometimes present a luminous appearance, and are then objects of great interest. One occurred in March 1818, to a party on Lochawe in Argyleshire, which imparted to the glassy surface of the lake, the boat, their clothes, and all the surrounding scenery, a luminous appearance, like a huge sheet of fire. Nor were the exposed parts of their bodies singular in this respect, for to the eye they all seemed to burn, although of course without any feeling of warmth. When they applied their hands to any of the melting Snow, the luminous substance adhered to them, as well as the moisture, and this property was retained by the Snow for twelve or fifteen minutes.

Thermo meter sc times ri during t descent Snow.

(615.) During the descent of Snow, the thermometer will sometimes gradually rise. Howard gives an example of an unusual fall at Plaistow, during which the thermometer at 10 A. M. stood at 19°, at 3 P. M. 22°, and at 9 P. M. 26°.

Compar tive des of Snov and Ra

(616.) All other things being the same, Professor Leslie supposes that a flake of Snow, taken as nine times more expanded than water, descends thrice as slow.

Actual mation Snow i huts of lar reg

(617.) In the Arctic regions, it has been observed by an able writer in the *Edinburgh Review*, that the wretched settlers, covered with a load of bear skins, remain crowded and immured in their huts, every chink of which they carefully stop against the piercing external cold. Soon, however, the whole of the inside becomes

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* *Annales de Chimie*, vol. v. p. 1.

Observed also at Tornea by Maupertuis in a room.

At St. Petersburgh also in a crowded assembly.

lined with a thick crust of ice; but if they happen for an instant to open a window, the moisture of the confined air is immediately precipitated in the form of a shower of Snow. Maupertuis, who was engaged in the great operation of measuring a degree of the meridian within the Arctic Circle, also remarks, that at Tornea, upon the opening of a door, the external air immediately converts the warm vapour of the chamber into Snow, *de gros tourbillons blancs.* Robison, the celebrated Natural Philosopher of Edinburgh, likewise remarked to Hutton the Geologist, as a beautiful example illustrating the truth of his theory, that in a crowded assembly at Petersburgh, when the company were suffering from the closeness of the room, a gentleman broke a window for relief, and the air rushing in, formed a visible condensation of snowy matter, having a revolving motion.

Frequent falls of Snow in Arctic regions in months of April, May, and June.

(618.) In the Polar regions, where every thing connected with Snow is exhibited on the grandest scale, Mr. Scoresby informs us it snows nine days out of ten, in the months of April, May, and June. With Southerly winds near the borders of the ice, or where moist air blowing from the sea meets with a cold breeze from the ice, the heaviest falls of Snow occur. In this case, a depth of two or three inches sometimes descends in an hour. Such heavy falls, it is said, frequently precede sudden storms. There seems no data to assist us in approximating to the annual average amount of Snow for the latitudes in which it falls.

Electricity of Snow.

(619.) Snow has generally been found electrified, and according to the observations of Schübler, it is oftener positive than negative, in the ratio of four to one.

Hail.

Hail has not attracted so much attention in this Country as on the Continent.

(620.) The phenomenon of Hail does not appear to have attracted so much attention in our own Country as on the Continent, where it has been made the subject of several most interesting Memoirs; and even at the very moment this Essay is passing through the press, the Academy of Sciences at Paris has announced it as another Prize question, and with conditions also of the most general and rigorous kind. In Great Britain our attention has been more occupied with rain, and we have happily not to lament the desolations produced by those tremendous Hail storms, which from time immemorial have ravaged the beautiful Provinces of France. Some places, from frequent catastrophes of this kind, have obtained the designation of Hail Countries. England, on the contrary, may with more propriety be denominated a Rain Country.

Formation of Hail a great paradox in Meteorology.

(621.) There is undoubtedly much in the origin and formation of Hail to awaken curiosity. Volta indeed regarded the formation of small flakes of ice—the kernels of future Hail-stones, in the month of July, during the hottest hours of the day—as one of the greatest paradoxes in Meteorology; and though we cannot hope, in the brief limits to which we are confined, to trace all the phenomena connected with it to their source, or produce observations, as the conditions of the learned Academy require, made in the very region of Hail, we may nevertheless remark, that the theory of Hutton, as just applied to the phenomena of Rain and Snow, seems better adapted on the whole to account for the formation of Hail, than any of the other theories that have been proposed.

Theory of Hutton seems adequate to account for it.

Precipitated moisture influenced by temperature of medium through which it passes.

A low temperature capable of producing Hail.

(622.) We have before remarked that moisture may be precipitated from the mingling together of masses of air of unequal temperatures, and unequal degrees of humidity; but the state in which the precipitated moisture reaches the Earth, must depend on the temperature of the medium in which it is formed, and on that through which it has to pass. We have already seen how moisture precipitated in this way produces rain; and how, under the influence of a lower temperature, it comes to us in the form of snow; and it would seem reasonable to attribute to a further decrease of heat, the power of still further crystallizing the descending atoms, and thus to give to them the decided character of Hail. The only difficulty in the way of an entire reception of the theory is, the comparative scarcity of Hail showers in the Winter season, the lowness of the clouds from which Hail in general results, and the magnitude of the masses in which it occasionally reaches the ground.

Phenomena which seem to indicate a common origin for rain, snow, and Hail.

Hard snow-balls and flakes of snow at same time.

(623.) There are however certain phenomena which have been remarked respecting the descents of rain, snow, and Hail, which would seem to imply a common origin for each, differences of temperature alone seeming adequate to explain their different formations. Howard has observed more than one instance of a huge nimbus, affording hard snow-balls and distinct flakes of snow at the same time; and Hail and rain are by no means an uncommon result of the same cloud. The magnitude of a cloud may indeed be such, or clouds at different elevations may be supposed to exist, which in an upper region shall afford Hail, in a lower region snow, and in a still lower region rain, differences of temperature existing in the supposed range, fully adequate to the production of these different phenomena. The same is also confirmed,—such are the capricious conditions of temperature in the air,—by rain actually forming in an upper region of the sky, and, descending into a colder stratum of the atmosphere, becoming converted into decided globules of Hail. Howard has an example of this in what he denominates a freezing shower, on the 19th of January, 1809. It consisted of hollow spherules of ice, filled with water, of transparent globules of Hail, and of drops of water at the point of freezing, which became solid on coming into contact with the bodies they fell on. The same observer also records, that on the 19th of July, 1803, a kind of icicle descended from the clouds, which was succeeded by large Hail, and finally by rain.

Freezing shower.

Large Hail succeeded by rain.

Rain succeeded by Hail.

Hail succeeded by rain.

(624.) A fine example, illustrating the junction of clouds, and of the resulting phenomena of rain and Hail, was observed at Tarragona on the 15th of September, 1828. Some large clouds were seen to advance with a South-East wind, at 7 A. M., discharging torrents of rain. Another great mass of cloud, driven by a Westerly wind, met the former with the greatest violence, producing thunder. As soon as the rain had ceased, an immense abundance of Hail descended, at first very small, but sensibly increasing to a very great size. Another example also occurred in North America about noon, on the 4th of June, 1814. A dark cloud appeared in the South-West, exhibiting an electrical appearance, some light clouds moving at the same time from the North-East, and apparently meeting the former. The united masses, after their junction, seemed to rise, and at length to attain an extraordinary height, their appearance inducing Dr. Crookshank, the observer, to predict Hail, and which presently fell in masses from 13 to 15 inches in circumference. Copious rain succeeded their descent. Arago likewise remarks, that Hail generally precedes storms of rain, and sometimes accompanies them; why then cannot they have a common origin, difference of temperature only modifying their states?

Hail may be formed either by day or by night according to the theory of Hutton.

(625.) A strong argument in favour of this application of Hutton may also be derived from the circumstance, that Hail may be formed either by day or by night in every climate, although its descent is most frequent in the former season. The theory of Volta[*] required the absolute presence of the Sun to act on the clouds, and by producing evaporation from the vesicular vapours which compose them, to form Hail as a result; whereas we know that very great Hail storms have occurred during the absence of the Sun; and the theory of Von Buch, which is founded on the effects of ascending currents of air, is open to a like objection.

Theory of Volta.

Objection to it.

Changes of wind frequent in Hail storms.

(626.) Examples of change of wind, and of the action of opposite currents, so necessary for the production of rain, are also frequent during Hail storms. In one which occurred to Mr. Howard in May 1809, the wind was first East, then South, afterwards West, again East, and finally West. Beccaria also recognises the same principle. "While clouds," says he, "are agitated with the most rapid motions, rain generally falls in the greatest plenty; and if the agitation be very great, it generally hails."

(627.) The descent of Hail in some Countries,

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[*] It may not be uninteresting to give a brief account of the theory of Volta in a note. That celebrated man grounded his theory of Hail on evaporation, and on the familiar electrical experiment known by the name of the *danse des pantins*, which consists of two metallic discs placed horizontally one above the other, the upper disc being suspended from the prime conductor of the machine, and the lower communicating with the ground, either immediately, or by the aid of a chain. A few pith balls placed on the lower disc, will, when the upper disc is electrified, shoot from the former to the latter surface, and back again; the oscillating motion being continued until the different electrical states of the two surfaces are at length equalized and rendered similar. Volta, in applying the results of this electrical toy to the great phenomena of Nature, supposed the black, stormy clouds which produce Hail, to be substituted for the metallic discs; and the small grains of Hail existing between them, exhibiting, by the electrical agencies of the clouds, motions like the pith balls in the *danse des pantins*.

There is certainly no difficulty in supposing, as Arago observes, two or more strata of unequally elevated clouds to exist at the same time, since we often see masses so disposed by the action of contending winds. When a storm seems beginning, small, greyish, detached clouds, sometimes immovable and sometimes disturbed, often appear under others of a different and much more extended form; and Volta has proved that the electrical transitions from a positive to a negative state, occur ten or twelve times, or even more, in a single minute.

But how, it may be asked, is the first embryo of Hail formed between the two clouds? The clouds, says Volta, are formed of hollow vesicles, the external surfaces of which are fluid. The myriads of these which form the upper surface of a cloud, must undergo, towards the South, a strong evaporation, both on account of the intensity of the solar rays, and the dryness of the air in which they swim. The elastic vapour thus produced by the solar heat, must first saturate the dry air through which it passes, and at length, by the low temperature of some superior stratum, become again reduced into a vesicular state, forming another cloud, differing in its electrical condition from the first. The upper cloud will have positive electricity, on account of that species of electricity being developed during the precipitation of vapour, the lower having changed its character to negative in consequence of the evaporation it has undergone. A diminished temperature at length may produce between the clouds icy particles, or Hail in a nascent state, which the opposite electrical states of the upper and lower clouds will cause to oscillate, until, by gathering matter from the surrounding moisture, they become at length enveloped in compact and opaque ice, and attain a size which, overpowering the electric forces, are compelled by Gravity to descend.

But this theory, apparently so simple, and at one time so popular on the Continent, has had objections opposed to it of a very formidable kind. Volta, indeed, having supposed that the first rudiments of Hail could only be produced by the action of the solar rays on the upper surfaces of clouds, found himself obliged to admit, that a Hail-stone which fell at three or four in the morning, before the Sun could possibly have acted upon the surface of a cloud, had oscillated at least ten or twelve hours between the surfaces of the oppositely electrified clouds; and Bellani, in some of the examples he has cited in opposition to the theory, has even adduced the instance of a storm in July 1806, which commenced before the rising of the Sun, and produced a prodigious quantity of Hail, when the preceding evening had displayed no indications whatever of a coming storm, throughout the whole extent of the visible horizon.

The experiment of the *danse des pantins*, continues Arago, furnishes moreover arguments more specious than solid. The electrified metallic plates, between which the pith balls oscillate, can neither be displaced nor divided. The particles, on the contrary, composing the clouds, are endowed either in their whole mass, or in their separate parts, with an extreme mobility. May it not therefore be aked how they alone remain immovable, and how they escape from the influence of those electrical forces which communicate the oscillatory motion to the interposed Hail-stones? Ought not the energetic action of these forces to bring into union the masses of clouds themselves?

It is also true that the experiment of the *danse des pantins* requires at least that one of the two electrified plates should be solid; for by substituting a sheet of water for the lower, as Bellani has done, the oscillatory motion takes place no longer: the balls, at the end of their first descent, penetrating the Liquid and rising no more. The clouds must present analogous phenomena: they cannot repel the Hail-stones until they have *touched* them; so that the gravitating force of succeeding Hail-stones, acting on those which have just come into contact with a cloud, must occasion some at least to penetrate it. A natural result of any long-continued system of oscillations must therefore be, the descent of Hail for many hours; whereas, on the contrary, Hail-storms are sudden and never continue long.

Arago, with his accustomed acuteness, has remarked in his commentary on Volta's theory, that did this oscillatory motion really exist in the atmosphere, it is somewhat remarkable that no one has ever perceived it. Hail clouds are commonly low, and travellers, continues that excellent and learned man, must have been oftentimes on mountains, within the range of the interval wherein these oscillations are performed; and added to which, the Hail-stones, in their ascent, must at least be sometimes brought into situations, where their *descending* courses never could have transported them; such as the lower parts of the roofs of cabins, or of very prominent rocks. But no such appearances have ever been remarked. Bellani, also, has made the important remark, that if electrified clouds sometimes possess the power of causing masses of ice of eight or ten ounces to oscillate between them, ought not the electrical energies of the clouds and the Earth sometimes to cause dust, gravel, and even stones, to be raised in calm weather? thus rendering, as he says, the atmosphere hardly fit for respiration, and producing to man more formidable evils than even Hail occasions.

M. de Perevoschtchikoff has endeavoured to support experimentally the objections made by Bellani against Volta's theory of Hail. He thinks that Volta lost sight of the principal cause of the cooling of clouds, and also of the concentric structure of Hail-stones. When the clouds, he remarks, consist of many thick strata, which gradually rise, they become an obstacle to the free distribution of the radiant heat from the Earth, which being reflected back again, produces that suffocating sensation which usually precedes a Hail storm. Above the clouds, however, the heavens are serene, and consequently radiation goes on freely from their upper surface. Hence the principal cause of the refrigeration, upon which depends the formation of the nucleus of the Hail-stone. The Specific Gravity of these nuclei being too great to allow of their remaining suspended in the cloud, they fall; and traversing different strata of clouds, they become covered at each by a fresh opaque coat of the Liquid congealed at their surface, the number of layers in the Hail-stone corresponding to the number of strata it has passed through. The Hail-stones, by concussion against each other, are supposed to have a rotatory motion given to them, tending to produce a spherical form.

It is proper to observe that this theory of the radiation of heat from the superior surfaces of clouds had already been proposed by Gay Lussac; but after all it must be reduced to that of Volta.

Hail in Europe generally by day.

appears to occur at particular periods. In the middle of France, Italy, Spain, &c., it commonly hails most abundantly during the warmest hours of the day, in Spring and Summer;* and in Europe generally, it falls principally during the day, though there are examples of great Hail storms which have taken place during the night. In August 1787, one ravaged the borders of the Lake Como, for an extent of 600 square miles, and began precisely at midnight; and another, no less disastrous, took place in August 1778 at the same hour; and a third in July 1806, just at the dawn of day. In our own country, generally, Hail is of rare occurrence in Winter,† if we except a sprinkling of small opaque grains, which in the former part of the night indicate the approach of a low temperature, and are found on the frozen ground, and on ponds in the morning, and sometimes by day after a descent of snow. In the Equatorial regions it seldom hails in places situated at a lower level than 350 fathoms; for although Hail is doubtless formed in the upper regions of the atmosphere, in that great division of the Globe, the warmth of the lower must prevent it from reaching the ground in that shape. Von Buch remarks, that it very rarely hails on mountains in the temperate climates of the Earth; and this he attributes to the low elevation of the clouds, from which Hail commonly descends.

Hail storms have definite limits.

Remarkable storm in France.

(628.) That Hail storms have definite limits, may be gathered from the tremendous storm which desolated so great a portion of France in July 1788.‡ It began in the South, and proceeded in two parallel bands from the South-West to the North-East; the extent of one of them being 175 leagues, and of the other 200; thus traversing nearly the whole length of that great Kingdom, and even a portion of the Low Countries. The mean breadth of the Eastern band was four leagues, and of the Western two, and what is very remarkable, the interval between the two bands, amounting to five leagues, was deluged with heavy rain.

Account of progress of this storm.

(629.) M. Tessier, who published an interesting account of this remarkable storm, informs us that its progress from South to North was at the rate of 16½ leagues an hour, and that the velocities of the two bands were precisely uniform. In the Western band it commenced hailing at Touraine near Loches at 6½ A. M.; near Chartres at 7½ A. M.; at Rambouillet at 8 A. M.; at Pontoise at 8½ A. M.; at Clermont in Beauvoisis at 9 A. M.; at Douai at 11 A. M.; at Courtray half an hour after noon; and at Flessingue at 1½ P. M. In the Eastern band, the storm reached Artenay, near Orléans, at 7½ A. M., corresponding precisely with the time of the Western band discharging itself near Chartres; at eight o'clock it arrived at Andonville in Beauce; the Faubourg St. Antoine in Paris at half-past eight; Crespy in Valois at half-past nine; Câteau Cambrésis at eleven, and at Utrecht at half-past two P. M. At each of these places, the continuance of the Hail was limited to seven or eight minutes.

Hail storm in Orkney, of confined extent.

(630.) Another example of the definite extent of a disastrous Hail storm is that which occurred in Orkney on the 24th of July, 1818, of which Mr. Neill has given an interesting account in the IXth volume of the *Transactions of the Royal Society of Edinburgh*. The thick layer of large Hail resulting from this storm, formed a tolerably well-defined belt across the Island, in a direction from South South-West to North North-East, and about a Scotch mile broad; the course of which we have endeavoured to illustrate, after Mr. Neill, in fig. 9. plate i., and beyond this line, on each side, the ground merely appeared "spotted with ice." In proof of the extremely local nature of the shower, persons who had been employed the whole day in digging turf, at a distance of little more than two miles Westward from what appeared to be the very centre of the storm, were wholly exempted from its effects. They had remarked a black cloud, and the lightning and thunder which resulted from it, but no Hail came near them; and the same thing was observed at a similar distance on the Eastern side. To the South also, the direction in which the storm came, its range was very confined. The peninsula of Deerness, belonging to the main land of Orkney, was directly in the line, and only seven or eight miles to the

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* It is worthy of remark, that rain falls at all seasons of the year, snow in winter, and Hail principally in Summer.

† This is the opinion of Howard, but Mr. Giddy's Tables for Penzance offer a decided exception. The following are the results of his Hail showers for the aggregate of the several months; during a period of twenty-one years.

January	23	July	1
February	25	August........	0
March	25	September	5
April	27	October........	17
May	7	November......	22
June	5	December	43

The month of August is here absolutely zero, and December affords the maximum.

‡ We extract the following notice of the calamitous consequences of this storm from the *Annual Register* of that time.

This tremendous storm was ushered in by a dreadful and almost total darkness which suddenly overspread the whole country. In a single hour the whole face of Nature was so entirely changed, that no person who had slept during the tempest, could have believed himself in the same part of the world when he awoke. Instead of the smiling bloom of Summer, and the rich prospects of forward Autumn, which were just before spread over the face of that fertile and beautiful country, it now presented the dreary aspect of universal Winter, in the most sterile and gloomy of the Arctic regions. The soil was changed into a morass, the standing corn beaten into a quagmire, the vines were broken to pieces, and their branches bruised in the same manner; the fruit trees of every kind were demolished, and the Hail lay unmelted in heaps, like rocks of solid ice. Even the robust forest trees were incapable of withstanding the fury of the tempest; and a large wood of chestnut trees in particular, was so much damaged, that it presented, after the storm, little more than bare and naked trunks. The vines were so miserably hacked and battered, that four years were estimated as the shortest period in which they could become again in any degree productive. Of the sixty-six parishes included in the district of Pontoise, forty-three were entirely desolated; while of the remaining twenty-three, some lost two-thirds, and others above half their harvest.

The same Historian also adds, that this unforeseen and irresistible calamity coming on at a season, already so strongly and unhappily marked by the violence of faction, by public discontent, and by political dissension, when all men were looking to, or apprehending some great convulsion in the State, produced such an effect upon the people in general, that the nation seemed to have changed its character; and instead of that levity and gaiety for which it had ever been distinguished, and which was ill concealed even in the most serious affairs, a settled and melancholy gloom now seemed fixed in every countenance.

M. Arago has lately remarked, that the damage done to a thousand and thirty-nine parishes on this occasion, amounted to 24,962,000 francs.

Leslie computes that Hail-stones sometimes fall with a velocity of 70 feet per second, which is at the rate of about 50 miles an hour. "Striking the ground with such impetuous force, it is easy," he says, "to conceive the extensive injury which a Hail shower may occasion in the hotter climates. The destructive power of those missiles in stripping and tearing the fruits and foliage, increases besides in a faster ratio than the momentum, and may be estimated by the square of their velocity multiplied into the mass. This fatal energy is hence as the fourth power of the diameter of the Hail-stone."

South South-West, yet remained untouched. The duration of the violent wind and heavy Hail, of the storm last described, continued about eight minutes.*

Appearance of Hail clouds.

Of low elevation.

(631.) The appearance of Hail clouds seems to be distinguished from other stormy clouds by a very remarkable shadowing. Their edges present a multitude of indentations, and their surfaces disclose, here and there, immense irregular protuberances. As a proof of the occasional lowness of Hail clouds, Arago remarks, that he has more than once seen clouds,—from which Hail would in a few minutes later have escaped abundantly, cover as with a thick veil the whole extent of a valley, whilst the neighbouring hills enjoyed at the very same time a pure sky and an agreeable temperature.

Forms of Hail very varied.

Change of wind alters them.

Six-sided pyramids changed into convex lenses.

(632.) The forms of Hail are very varied, but all Hail-stones resulting from the same shower, generally present considerable uniformity, when they fall nearly on the same level. It has been remarked that Hail-stones of the same storm, are found to be much smaller on the tops of mountains than in the neighbouring plains. If, however, any alteration takes place, either in the temperature or the wind, the figures of the Hail-stones become immediately changed. On the 7th of July, 1769, M. Adanson observed six-sided pyramidal Hail-stones to descend at six P. M.; but on the wind changing to the North-East, the Hail-stones which then descended, were in the form of convex lenses, and so transparent, that they increased the dimensions of objects without at all distorting them. In the great storm which desolated France, some of the Hail-stones were globular, others elongated, and others armed with different points,—probably the result of altered temperature or wind.

Flakes of spongy snow at their centres.

Surrounded by concentric strata of ordinary ice.

Sometimes transparent, sometimes opaque.

(633.) Very frequently in the centres of Hail-stones, small flakes of spongy snow are to be found; and generally speaking, this is the only dark part in them, the concentric strata with which it is surrounded having all the transparency of ordinary ice. Hence it has been supposed by many, that the internal and external parts of these stones are not formed under the same conditions. Sometimes, indeed, large Hail-stones have been found which present this snowy texture at their centres; but around their central parts, concentric layers, alternately transparent and opaque, are disposed. Leslie imagines the spongy texture to result from an atom of water having been suddenly frozen, and particles, of perhaps rarefied air, suddenly driven from the surface towards the centre. In his curious experiments on the production of ice by evaporation, in a receiver containing air very much rarefied, he constantly remarked the ice to be more porous and less transparent than when formed under the ordinary pressure of the atmosphere.

Surface of Hail covered with dust like fine flour.

Other instances.

(634.) Sometimes a small kind of Hail occurs, which is scarcely solid, and whose surface appears as if covered with particles of dust like very fine flour; and from its general texture it seems to occupy a kind of intermediate rank between Hail in its ordinary state and snow. This sort never falls during Summer in Southerly Countries. Another small kind of Hail is also found, exhibiting no trace of a central snowy flake, but differing in transparency from the former.

Hail-stones observed b Humboldt in the Andes.

In Orkney polished like marbles.

(635.) Whilst ascending the volcano of Poracé in the Andes, Humboldt observed Hail-stones from five to seven lines in diameter, formed of layers of different degrees of transparency, and not only flattened at their poles, but so much increased in their Equatorial dimensions, as to permit rings of ice to be separated from them with a very slight blow. Twice before he observed the same phenomenon, in the mountains of Bareuth, and near Cracow. In the storm before adverted to, which fell in Orkney, some Hail-stones were found as finely polished as marbles. Their colour also was worthy notice, being generally of a greyish white, not unlike fragments of light-coloured marble.

Hail-stones at Bonn delineated.

Sections.

(636.) Some interesting examples of Hail-stones were observed at Bonn on the 7th of May, 1822, of which illustrative figures have been given. Their general size was about an inch and a half in diameter, and their weight 300 grains. When whole, which was not always the case, their general outline was elliptical, with a white and nearly opaque nucleus of a round or spheroidal figure in the centre, about which were arranged concentric layers, increasing progressively in transparency to the outside. Some of them exhibited a beautiful stellular and fibrous arrangement, the result of rows of air bubbles disposed in different radii. Fig. 70 denotes the external form of one, and fig. 71 is the section of another having the concentric lamellar structure and system of radiation; and fig. 72 represents a third, cut in the direction of its shorter axe.

Forms observed by M. Delcro

Composed of pyrami dal parts.

(637.) M. Delcros has also given some figures of Hail-stones, having a concentric lamellar structure, and with a stellular fibrous arrangement. Fig. 73 is a section of one, where the surface appears covered with pyramidal forms, but having their summits somewhat blunted by incipient melting. When masses of this peculiar structure are burst asunder from any cause, the fragments disclosed are pyramidal, as in figures 74 and 75, thus forming what has been termed pyramidal Hail. And this peculiar formation would seem to be very common, at least in France, since M. Delcros has been able to trace it during ten years' observation. The apex, he remarks, is sometimes found wanting, but when present, it is apparently part of a hard nucleus. These forms were observed by M. Delcros in great perfection in a storm which happened at La Bacconière, in the Department of Mayenne, on the 4th of July, 1819.

Observed also by Lindsay.

(638.) Examples of pyramidal Hail-stones were observed likewise by Mr. Lindsay, on the 29th of November, 1823, at Aberdeen. At five P. M. there fell a shower, composed at first of distinct drops of rain, but which afterwards became changed into violent Hail. The Hail-stones were hard, and in almost every case presented five surfaces—four perfectly plane, constituting the sides of an irregular pyramid, and the remaining one spherical, serving as a base. These are represented in figs. 76 and 77. The spherical surface, to the depth of $\frac{1}{20}$th or $\frac{1}{30}$th of an inch, appeared solid and transparent.

Hail-sto of irregu polyhed forms.

(639.) Some Hail-stones have been observed of irregular polyhedral forms, and composed of an assemblage of smaller Hail-stones, united previous to their reaching the Earth. In some cases, icy masses have been

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* This storm, considering its limited extent, was productive of very disastrous consequences. Mr. Neill informs us, that of a large flock of tame geese feeding on a down, many were killed on the spot, and the others so much injured, that all of them pined away, and died in a short time. Great numbers of small birds, as skylarks, starlings, corn-buntings, and wheat-ears, were found dead, and afterwards collected into heaps by the boys belonging to the farm. On the shore were observed numbers of rock-pigeons, hooded-crows, guillemots, and ducks, which had been killed at sea by the Hail and left by the receding tide. A boy received a severe blow on the back of the neck, which stupified him, and produced a contusion, from which he had not recovered after the lapse of some months.

found,—the result of a storm, resembling fragments of a vast plate of ice, broken in its descent to the Earth.

Hail-stones with pyritic nuclei.

(640.) Some Hail-stones having pyritic nuclei have been noticed by Professor John of Berlin. They fell at Sterlitamak, and contained a stony and crystallized nucleus. Their colour was brown, like the auriferous pyrites of Beresowsky in Siberia, and their surface shrivelled and resplendent. The crystal formed a flattened octahedron, with salient edges. The diagonals of the base were respectively four and five lines, and the distances of the summits two lines. In some cases, the four angles of the base were truncated.

Hail of blood colour.

(641.) At Parama de Guanacas, Humboldt and Bonpland saw Hail fall of the colour of blood.

Elasticity of Hail-stones.

(642.) On some occasions, as in a storm in the Department du Gard, on the 21st of May, 1828, such was the hard and elastic character of the icy masses, that those which fell on the stones rebounded, often without breaking, to the height of several yards.

Hail-stones projected almost horizontally.

(643.) Howard records a case wherein Hail-stones were projected from a cloud almost horizontally; and their velocity was such, that in many instances a clear round hole was left in the glass they pierced; and one large pane had two such perforations distinctly formed in it. The advocates of the electrical origin of Hail explain these oblique discharges by two electrical clouds drawn vertically towards each other, the Hail issuing in the resultant of the parallelogram of which the component forces are Gravity, and the common direction of the clouds. A change in the density of the air, however, is sufficient to account for the approach of clouds to each other, and thus the phenomenon in question becomes reduced to the theory of Hutton.

Noise heard before descent of Hail.

(644.) Arago remarks, that sometimes before the descent of Hail, a noise is heard,—a particular kind of cracking, which it would be difficult to describe in any other way, than by comparing it to the emptying of a bag of walnuts. This is accounted for by some Meteorologists, by supposing the Hail-stones to be driven by the wind against each other, in the clouds which carry them. Others imagine the Hail-stones themselves to be strongly and differently electrified, and consider the cracking in question to result from electrical discharges a thousand times repeated.

Frequency of electrical changes during Hail.

(645.) As a proof of electrical action, it is sufficient to follow for a short time the movements of an atmospherical electrometer on the approach of Hail, when the electricity will be found frequently to change, not only in intensity, but also to pass from positive to negative, and *vice versâ*, ten or twelve times in a minute.

Table of remarkable Hail-stones.

(646.) In the succeeding Table we have recorded some authentic instances of Hail-stones of considerable dimensions and weight, with the dates and localities of their descent.

TABLE CXL.

Date.	Place.	Authority.	Weight or Dimension.	Remarks.
April 4, 1697.	Flintshire.	Halley.	5 ounces.	Many of this size appear to have fallen.
May 4, 1697.	Hitchin in Hertfordshire.	Robert Taylor.	A perimeter of 14 inches.	Hence it may be inferred that they had a diameter of more than four inches.
May 15, 1703.	Le Perche.	Parent.	As large as his fist.	
July 11, 1753.	Toul.	Montignot.	3 inches in diameter.	Of polyhedral forms, and made up of an assemblage of small Hail-stones, united before they reached the Earth. They fell at six P. M.
Aug. 19, 1787.	Como.	Volta.	9 ounces.	
July 13, 1788.	From the middle of France, to the Low Countries, and Holland.	Tessier, and adopted by Arago.	Half a pound.	The largest stones weighed half a pound. Their forms were various. Some round.
July 15, 1808.	In Gloucestershire.	Howard.	From 3 to 9 inches in circumference.	It was remarked, that these stones appeared like fragments of a vast plate of ice, which had been broken in its descent to the Earth.
June 4, 1814.	North America.	Dr. Crookshank.	13 to 15 inches in circumference.	These appeared to be aggregates of many.
July 24, 1818.	Orkney.	Mr. Neill.	From four ounces to nearly half a pound.	Of a greyish white colour, not unlike fragments of light coloured marble.

Difficulty in accounting for such large masses.

(647.) We conclude with the single remark, that there is certainly a considerable difficulty in satisfactorily accounting for the formation of such masses as the preceding Table records. The clouds from which Hail descends, are, as we have before remarked, commonly very low; and it has hence been inferred that a Hail-stone can hardly employ more than a minute in reaching the ground. But in so short a time, it can scarcely be supposed, as Arago properly observes, whatever may be the dampness of the air, that the primitive kernel can cover itself with so many envelopes, as ultimately to acquire the size of the egg of a hen. The theory of Volta has thus an air of probability about it, when he supposes that the Hail, being once formed in the atmosphere, may remain suspended even for hours in space, and thus continue to acquire new accessions of matter, until the Gravity of the stones overcomes at length the electrical attractions by whose power they are suspended. Let us hope, that the new inquiries to which the Prize question lately proposed by the Academy of Sciences will probably lead, may remove the difficulties which unquestionably still cling to the subject.

On Dew.

Dew depends on radiation of heat and condensation of vapour by cold.

Bodies become colder than air, before Dew forms on them.

Cold formerly thought to be an effect of the moisture deposited.

(648.) An investigation of the subject of Dew, involves a multitude of most interesting phenomena, which, in the hands of Dr. Wells, have been perfected into a very beautiful and instructive theory. Strictly speaking, this theory will be found to depend upon two single principles, in constant activity around us,—the radiation of heat, and condensation of invisible vapour by cold; and although the discovery of the now apparently evident principle by Dr. Wells, that bodies must become colder than the neighbouring air, *before* Dew can be formed on their surfaces, might, according to the ingenuous and modest opinion of that estimable man, have been made at any time since the invention of the thermometer,* yet when we consider, that prior to the publication of his *Essay on Dew*, the cold which accompanies Dew† was constantly regarded as an *effect* of the moisture deposited, instead of the *cause*, and that from the time of Aristotle, the prejudices of the vulgar, as well as the opinions of Philosophers, had concurred in giving every possible weight to the opinion, we cannot but admire the patience and sagacity, and the pure spirit of inductive research which enabled him, in the midst of sometimes apparently discordant phenomena, to trace a principle entirely the reverse; converting that which had ever been regarded as a *cause* into an *effect*, and proving by a single principle, that a body ALWAYS became colder than the air in contact with it, before Dew could be deposited on its surface, and finally raising from it a theory, which should satisfactorily account for all the varied and beautiful phenomena of Dew, and harmonizing in every way with the established laws of Heat.

The cold which is the cause of Dew is the effect of radiation.

(649.) The cold here referred to as the cause of Dew, is the result of radiation. The power of radiation is enjoyed by all bodies in different degrees, and is developed both by day and by night. In our ordinary experience, we are most familiar with its effects by day, but there are phenomena quite as remarkable disclosed by its agency by night. The Earth covered with a variety of soils, the herbage of all kinds which adorn and beautify its surface, the rocks, the metals, and other bodies which the industry of Man has converted to his use, all possess this power in some shape or other, and all contribute to that infinite diversity of phenomena which the subject of Dew so abundantly unfolds.

(650.) But how, it may be asked, can these varied effects be traced? Every clear and tranquil night discloses in an ample degree their power, the green mantle of nature soon becoming colder than the surrounding air. Each blade of grass throws out a portion of its heat into empty space, but receives from the interminable void around no heat in return. The lower parts of the grass may communicate some of the Earth's internal store of heat by conduction; but the radiating power, more active, at least in this case, will at length cool the grassy surface below the temperature of the surrounding air. These effects will be rendered manifest, by placing one thermometer on the grass, and another at some moderate distance above it.

Examples of bodies having high radiating powers,

and of the great depression of temperature they undergo.

(651.) But this same property may likewise be traced in other substances besides the green covering of the Earth. Polished metal and polished glass will exhibit it in very opposite degrees; and among the metals a considerable diversity will be found, not only in their polished state, but also, when, from any mechanical action, their surfaces have acquired different degrees of roughness. It will also be found, that not only the substance and surfaces of bodies exercise a powerful effect on the phenomena of radiation, but that their texture likewise exerts a very great influence. Those of a close and compact kind radiate feebly, but bodies of a looser texture will be found eminently favourable to radiation. The delicate shining thread of the gossamer which sometimes covers our hedges and fields, swansdown—a substance exceedingly well adapted for observing the phenomena of Dew,—fine raw silk, masses of unwrought cotton, flax, wool, hair, fresh unbroken straw, and shreds of white paper develope this radiating power in a very high degree. Substances of this nature are often found twelve or fifteen degrees colder than the ambient air; and Dr. Wells remarks, that in a Country like Russia, in the season of Winter, a difference of thirty degrees may sometimes appear on a calm and tranquil night, between a small thermometer placed with its naked bulb on the middle or leeward side of a stratum of a downy substance, and a similar thermometer enclosed in a case of gilt paper, and suspended in the air a few feet above.

What conditions of the atmosphere are most favourable to radiation.

(652.) It will be found, however, when pursuing the inquiry, that some conditions of the atmosphere are much more favourable to the developement of the radiating power than others; and that when the night is perfectly clear, and an unclouded sky prevails in every direction around, and no terrestrial object intervenes to diminish the extent of view, a body exposed horizontally will develope this energy in the highest possible degree. Hence it is, that bodies which radiate their heat most freely, and at the same time possess the feeblest conducting powers, will, under such circumstances, become the coldest.

Effects of clouds.

They diminish the Earth's radiation.

Alternate states of a clear an cloudy sk depress and raise the temperature.

(653.) If, however, the clearness of the atmosphere be in any degree impaired by the presence of clouds, some change in the radiating power at once takes place. Even a solitary cloud in the zenith, as in fig. 1, plate iv., will occasion this change, and the effect becomes manifest on a delicate thermometer in a very short time. If the sky becomes more overcast, the thermometer will still rise in temperature, indicating the radiating power to be still more impaired; and in an entirely cloudy night, it may be said to be suspended altogether. If the clouds suddenly disappear, the radiating power is at once restored; and a succession of clouds passing the zenith, with alternate intervals of clear sky, will be marked by corresponding changes in a thermometer,—the presence of a cloud, as before observed, increasing the temperature, and its absence at once diminishing it. Dr. Wells

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* Mr. Six of Canterbury mentioned in a Paper communicated to the Royal Society, that on clear and dewy nights, he always found the mercury lower in a thermometer laid upon the ground, than it was in a similar thermometer suspended in the air, six feet above the former. But it is one thing to mark a difference of this kind, and another to trace its Philosophical relations, and make it the foundation of a refined theory.

† Dr. Wells remarks that Dew is often spoken of as being cold, by popular writers. Thus Cicero and Virgil apply to it the epithet of "*gelidus*," Milton that of "chill," and Collins that of "cold." Of the same import is a passage in Herodotus, in which it is said, that in Egypt the crocodile passes a great part of the day on dry land, but the whole of the night in the Nile, this being warmer than the atmosphere, and the *dew*. Among Philosophers, however, Dr. Wells thinks, Mr. Patrick Wilson of Glasgow was the first who ever suspected the existence of such a conjunction.

Example.

quotes a case wherein the temperature of a grass-plot at half-past nine was 32°, but twenty minutes later was raised to 39°, the sky in the mean time being covered with clouds. On the clouds disappearing, the temperature was again restored to 32°.

How clouds produce these effects.

(654.) The cause of these varied phenomena,—and they are most interesting when pursued through all their relations,—result from a general law which seems more or less active at all times,—the reciprocal radiation of bodies. It is in virtue of a law of this sort, that the clouds return to the Earth the whole or a great part of the heat which may have been radiated from it; although dense clouds may sometimes be formed so high, as to be colder than the Earth, and thus to radiate to it less heat than the ground imparts;—accounting, therefore, for the phenomenon sometimes observed on cloudy nights, of good radiating bodies being several degrees colder than the air.

Other bodies raised above the ground produce a similar effect.

(655.) But it is not only by the presence of clouds in the atmosphere, that the power of radiation can be checked. The interposition of any bodies whatever, between the radiating surface and the sky, will produce the same effect. The thinnest cambric handkerchief,* or even a piece of open wirework placed at a moderate elevation above the ground, as in figures 2 and 3, have the power of checking the force of radiation, and the fact may be readily verified in grass. Trees, houses, or whatever objects intercept the view of the sky, exercise a proportional effect; and so powerful in this respect are the influences of particular localities, that two bodies, in themselves precisely similar, and destined to illustrate the same experiment, may, nevertheless, from the influence of surrounding objects, present very opposite results. A metallic plate in one field, may remain free from moisture during an entire night, when a plate precisely similar, in another field, will be covered with innumerable particles of Dew. The existence of a gravelled walk near the scene of observation, is sufficient to modify an experiment; and Dr. Wells, in remarking that a portion of the garden in which he performed his experiments was employed in raising culinary vegetables, exhibited by no means too much nicety respecting the effect of local circumstances in influencing his results.* One general remark may therefore be made, and it is one of great importance,—whatever cause diminishes the aspect of the sky, whether it be a terrestrial object on the plane of observation, or a distant cloud floating in the air, will impair, in some degree or other, the force of radiation.

Necessity of attending therefore to localities.

Caution of Dr. Wells.

The radiation of a body must at length cause moisture to be condensed on it.

(656.) The result of this radiating power, in whatever degree it be developed, must, at some temperature or other,—dependent on the conditions of the body itself, and on favourable atmospheric circumstances around it,—occasion a condensation of humidity on its surface; and it may be observed as a confirmation of all that has been advanced on the necessity of an ample exposure to

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* "I had often," says Dr. Wells, "in the pride of half knowledge, smiled at the means frequently employed by gardeners, to protect tender plants from cold, as it appeared to me impossible, that a thin mat, or any such flimsy substance, could prevent them from attaining the temperature of the atmosphere, by which alone I thought them liable to be injured. But, when I had learned, that bodies on the surface of the Earth become, during a still and serene night, colder than the atmosphere, by radiating their heat to the heavens, I perceived immediately a just reason for the practice, which I had before deemed useless. Being desirous, however, of acquiring some precise information on this subject, I fixed, perpendicularly, in the earth of a grass-plot, four small sticks, and over their upper extremities, which were six inches above the grass, and formed the corners of a square, the sides of which were two feet long, drew tightly a very thin cambric handkerchief. In this disposition of things, therefore, nothing existed to prevent the free passage of air from the exposed grass to that which was sheltered, except the cambric handkerchief. The temperature of the grass, which was thus shielded from the sky, was upon many nights afterwards examined by me, and was always found higher than that of neighbouring grass which was uncovered, if this was colder than the air."

The same effect also was noticed by him, when the sheltering substance was at a much greater distance. Thus he had "four slender posts driven perpendicularly into the soil of a grass field, and so disposed that their upper ends were six feet above the surface, forming the angular points of a square having sides eight feet in length. Over the tops of these posts was thrown an old ship flag of a very loose texture," and it appeared to Dr. Wells from different experiments, that the higher shelter had the same efficacy with the "lower, in preventing the occurrence of cold upon the ground, greater than that of the atmosphere in a clear night, provided the oblique aspect of the sky was equally excluded from the spots on which the thermometers were laid." When a thin handkerchief like this, is placed even vertically, it sensibly increases the warmth of the grass. To diminish radiation, contact should at all times be avoided. Dr. Wells found the warmth of grass, sheltered by a cambric handkerchief raised a few inches in the air, was three degrees greater than that of a neighbouring piece of grass, sheltered by a similar handkerchief in actual contact with it. On another occasion it was four degrees.

Mr. Daniell, in his able Essay on *Climate considered with regard to Horticulture*, remarks, "that the radiation is only transferred from the tree to the mat, and the cold of the latter will be conducted to the former in every point where it touches."

* The choice of a suitable locality for performing experiments on Dew, is of much greater importance than we should at first suppose. A wall, a house, or some distant trees will modify results, and in some cases prevent Dew from being deposited at all; and this will often be the case with regard to metals. It was from an inattention to circumstances of this kind, that Le Roi imagined that Dew was never deposited from the air of cities; whereas at the time his experiments were performed, either the conditions of humidity or temperature were not favourable to the formation of Dew; or what is more probable, the place of observation was so surrounded by lofty buildings, as to diminish, or prevent altogether, the radiation necessary for its formation. Experiments therefore performed in a garden situated in the heart of a great city, must often lead to results very different from that which would have been obtained in an open plain. And from a circumstance of the same kind, doubtless it was, that both Muschenbroek and Dufay inferred that metals were altogether destitute of the power of receiving Dew; although it is now known, that many most interesting phenomena of the kind are disclosed by them.

Dr. Wells, when he undertook his inquiries respecting Dew, described the exact locality. "I think it right," he observes, "to describe the place, where by far the greater part of my observations on Dew were made. This was a garden in Surrey, distant by the public road, about three miles from the bridge over the Thames at Blackfriars, but not more than a mile and a quarter from a densely built part of the suburbs on the South side of that river. The form of the garden was oblong, its extent nearly half an acre, and its surface level. At one end was a dwelling-house of moderate size, at the other a range of low buildings; on one side a row of high trees, on the other a low fence, dividing it from another garden. If this fence had been absent, the garden would have been on the latter side entirely open. Within it were some fruit trees, but, as it had not been long made, their size was small. Towards one end, there was a grass-plot, in length 62 feet, and nearly 16 broad, the herbage of which was kept short by frequent mowing. The rest of the garden was employed for the production of culinary vegetables. *All of these circumstances, however trifling they may appear, had an influence on my experiments, and most of them, as will hereafter be seen, must have rendered the results less remarkable than they would have been, if they had occurred on a wide open plain, considerably distant from a large city.*"

As an example of his great caution respecting the influence of surrounding objects, he remarks on one occasion, "It seems certain that the houses surrounding Lincoln's-inn-fields, had an influence upon my thermometers, during my experiments there at night, beyond what arose from their merely retaining a quantity of heat, equivalent to that which they received from the surface of the garden."

Popular belief that Dew falls destroyed by a simple experiment of Dr. Wells.

the sky, that the first and simplest experiment which can be performed in illustration of the actual deposition of Dew, at once proves its correctness, and destroys the popular belief in the *fall* of moisture from the sky in an invisible form. "I placed," observes Dr. Wells, "on several clear and still nights, 10 grains of wool upon the middle of a painted board, 4½ feet long, 2 feet wide, and 1 inch thick, elevated 4 feet above the grass-plot, by means of 4 slender wooden props of equal height; and at the same time, attached, loosely, 10 grains of wool to the middle of its underside. The two parcels were consequently only an inch asunder, and equally exposed to the action of the air. Upon one night, however, I found the upper parcel had gained 14 grains in weight, but the lower only 4. On a second night, the quantities of moisture acquired by like parcels of wool, in the same situations as in the first experiment, were 19 and 6 grains; on a third 11 and 2; on a fourth 20 and 4; the smaller quantity being always that which was gained by the wool attached to the *lower* side of the board."

Effect of limiting the view of the sky illustrated by experiment with a cylindrical vessel.

(657.) Again, as another experiment illustrating the effect of exposure to the sky, Dr. Wells placed upright on the grass-plot, a hollow cylinder of baked clay, the height of which was 2½ feet, and diameter 1 foot. On the grass, surrounded by the cylinder, were laid 10 grains of wool, which, in this situation, as there was not the least wind, would have received as much rain as a like portion of wool fully exposed to the sky. But the quantity of moisture obtained by the wool surrounded by the cylinder, was only a little more than 2 grains, while that acquired by a similar portion of wool, fully exposed, was 16 grains. In this case the amount of direct radiation to the sky A B, was limited to the diameter C D of the cylinder, see fig. 4, and the small increment of moisture gained by the wool within it, might have been anticipated. Harvey traced the effect of a diminished aspect of the sky,[*] by employing cylindrical and the frustrums of conical vessels, of a common diameter at the base, and of a common altitude. The greater the upper diameter of a vessel, all other things being the same, the greater was the amount of Dew on equal masses of wool placed at the bottom; and a sensible diminution in the quantity of Dew was perceived, whenever the upper end of a vessel had only a few narrow detached slips of wood placed above it, as in figures 5 and 6. In some shorter cylinders, he found that wire-work of various degrees of fineness, produced very sensible decrements of the kind.

Effects of even a few slips of wood.

Apparent exception to the principle explained.

(658.) An apparent exception to this general principle is mentioned in the XVIIth volume of the *Journal of Science*. On an evening when the deposition of Dew was expected to be considerable, a plate of polished tin was placed gently on long grass, and its weight compressing the herbage on which it rested, necessarily caused the polished surface to be surrounded on all sides by grass, reaching twelve inches above it. At eighteen inches above the ground, or two inches above the average height of the grass, a similar plate was placed on slender props, as in figure 7. Now the latter plate having its surface thus exposed to the entire canopy of the sky, and the former having its view confined to a comparatively small space, in the zenith of observation, it might be inferred from the principle above announced, that the former would have gained more moisture than the latter; whereas the plate surrounded by the long grass, had its superior surface completely covered with minute but distinct particles of moisture, and the plate elevated above the grass was perfectly dry. But the principle of Dr. Wells, as remarked by the author of the Paper in question, is evidently limited to the consideration, that the bodies are in other respects placed under like conditions. The cooling power of the grass surrounding one plate, must necessarily have extended its influence to the metal; and by lowering its temperature considerably, have occasioned the copious deposition observed. The upper plate not being in contact with the grass, permitted the air to pass freely on each side of it; and being itself a bad radiator, attained no condition during the night favourable to the deposition of Dew.

Influence of an oblique aspect of the sky.

(659.) The effect of an oblique aspect of the sky is also clearly shown by another experiment of Dr. Wells. Ten grains of wool placed at C, fig. 8, directly under the middle of the raised board, could only be influenced by the portions of the sky comprised between A D and B E; the interval between the points A and B producing no effect on C, in consequence of the interposed board F G. Accordingly Dr. Wells found, after repeating the experiment on three several occasions, that the mass of wool at C, gained only 7, 9, and 12 grains of moisture respectively, at times when similar parcels of wool, laid upon another part of the grass, entirely exposed to the heavens, gained 10, 16, and 20 grains severally.

Influence of trees i this way.

(660.) Similar effects also may frequently be traced in cases where wide spreading trees prevail. Around the trunk of a tree, and as far as its branches extend, less Dew will at all times be found, than in the open space beyond. In the case of fig. 9, the space between A B, determined by vertical lines C A and D B from the extremities of the branches of the tree, is prevented by the foliage of the tree from radiating its heat to the upper sky, and hence the space referred to enjoys only the oblique radiation below A C and B D. The temperature within A B must hence be greater than in the free open field, where no interruptions to radiation exist, and a less amount of Dew consequently be found.[*]

Horizont surfaces more de than per- pendicul

(661.) Gersten long ago remarked, without being able to account for it, that horizontal surfaces are more abundantly covered with Dew than those which are perpendicular, an effect, however, which is now clearly to be traced to the diminished radiation of the latter. Harvey placed a hollow cube of block tin in a meadow, two inches above the herbage, with its vertical faces equally exposed to the cloudless horizon. To these faces, and to the upper surface of the cube, equal parcels of wool were attached, with equal radiating surfaces. At five

Experiments.

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[*] Connected as the formation of Dew is with temperature, we may trace the first indications of the effects of a diminished aspect of the sky, in the suggestion made by Dr. Black,—to whom Chemistry is under everlasting obligations, to Mr. Patrick Wilson, Professor of Astronomy at Glasgow. On the 24th of January, 1784, that celebrated man suggested an experiment of placing some gauze over a thermometer. Mr. Wilson accordingly fastened a piece of open gauze to a hoop of eight inches diameter, and an inch deep; when the sheltered thermometers were found commonly to rise nearly two degrees.—*Edin. Trans.* vol. i.

[*] Milton beautifully alludes to this when in his *Paradise Regained*, he says:

> Full forty days he pass'd, whether on hill
> Sometimes, anon on shady vale, each night
> Under the covert of some ancient oak,
> Or cedar, to defend him from the Dew.

the next morning, the upper mass of wool had gained fifteen grains of moisture, and the parcels attached to its vertical surfaces, equal increments of five grains; the equality resulting from the perfectly tranquil state of the air.

Effects of different obliquities illustrated.

(662.) On surfaces variously inclined, different amounts of Dew will be found, in virtue of the change that different obliquities produce on the radiating powers of bodies. Hence we may account for the diversities sometimes to be met with in the amounts of Dew obtained on the same substance in different localities. Thus, if fig. 10 be supposed to represent a vertical section of a country, where considerable inequalities of surface prevail, and we further suppose the soil and herbage which cover it to possess, independently of these inequalities, the same radiating power; then will the results of Dew obtained on the open and horizontal surface A B, exceed those deposited on the inclined ground B C. An observer situated also at C D, although enjoying a surface equally level with A B, will nevertheless obtain smaller amounts of Dew, on account of the place enjoying a less expanse of sky; and an experiment performed in the valley at E will again disclose other results. In like manner, a mass of wool placed at H on the plane F G, having a common level with A B, may nevertheless gain less dew, from the aspect of the sky being partially cut off by the walls or hedges at F and G. How different then must be the results of an observer who may carry on his observations in a woody and enclosed country like the foreground of fig. 11, where the radiating power is checked on every side, and another who may be situated on the open surface of the high ground above;* and how different both the results of these, from what an experimenter would find on the inclined ground visible in the same scene. The choice of a locality, as before remarked, must therefore be of great importance in all inquiries relating to Dew.

Experiment illustrating effects of radiation and deposition of Dew.

(663.) Another beautiful experiment illustrating the effects of a free aspect of the sky, may be performed by suspending a glass globe a little above the ground. On a perfectly tranquil night, and in a free open space, the first particles of moisture will be formed on the very zenith of the ball; and as the superior hemisphere of the ball continues to lose heat by radiation, these atoms of Dew will increase in size, and at the same time others will begin to be deposited around them, but of gradually decreasing dimensions, as they recede from the zenith, until at length they will be found to terminate in a slight film of moisture round the Equator of the ball. This beautiful effect is attempted to be illustrated in fig. 12. If, however, the radiating power be checked on any part of the ball, the uniformity will be destroyed. A similar effect may be produced by exposing a sheet of paper to the evening sky, having its surface disposed in round ridges as the section in fig. 13. After some time the summits of all the raised parts will be found with large particles on them; and from these, others diminishing in size may be traced; until at length, in the hollow parts of the paper, particles only of the smallest possible kind will be found. The gradation of these watery atoms will be found worthy of notice. So also if a dead beetle be exposed, a like gradation of the particles of Dew will be found, as in fig. 14. A similar effect may also be discovered upon the back of a sheep, which may have been reposing quietly on the ground. The woolly coating of the animal will be found covered with a great abundance of Dew on its upper part; but round its sides the moisture will be less abundant; and a limit may almost be traced to it in the greatest horizontal section of the animal, as A B C, fig. 15.

Glass best adapted for observing formation of Dew.

(664.) Plane pieces of glass horizontally disposed, are best adapted for observing the actual formation of Dew. The appearances on surfaces of this kind are altogether similar to those which occur on them when exposed to the action of steam a little warmer than itself. The exposed surface has first its lustre diminished by a slight damp uniformly spread over it, as in fig. 16; but as the moisture increases, it gathers into flat drops of very dissimilar forms. These drops are at first very small, but afterwards they enlarge, and run into each other, and by forming streamlets, cause a great portion of the moisture to escape from the body, as denoted in the figures 17, 18, 19, and 20.

Example of its progressive formation.

Wool well adapted both for obtaining and retaining Dew.

(665.) It is an important object, however, in a pursuit of this nature, to obtain a substance admitting of the ready formation of Dew, and at the same time with a power of retaining it for the purpose of examination. Such is wool. Many precautions, however, are necessary both in selecting and using it. Uniformity in the fibre is necessary, and great care should be taken that the masses selected for comparative observations, should in all cases expose equal surfaces to the sky. Equality of mass or weight by no means implies equality of radiating surface. The same mass of wool may be disposed in a variety of forms, and each form differ in the quantity of its radiating surface. Ten grains of wool made into the form of a ball, will obtain much less Dew than an equal quantity disposed into a flattened form. In the globular form, the upper half only can obtain Dew, and the particles will diminish in size to the Equator A B, fig. 21, as already remarked in the glass globe; whereas in the mass of equal weight disposed into a flattened form, as fig. 22, the whole of its upper surface must uniformly gain Dew, and in particles equal in size to those deposited on the zenith of the globular mass. The surface of this flattened form also may be obviously very much changed. Much precaution, therefore, is necessary in attending to the deposition of Dew on wool.

Uniformity of fibre necessary. Equal radiating surface necessary.

Comparison of different forms into which wool may be disposed.

Metals present a striking contrast to glass and wool in formation of Dew.

(666.) While glass and wool, therefore, are distinguished for the readiness and abundance with which Dew is deposited on their surfaces, the metals afford examples entirely the reverse. Such is the resistance indeed which polished metallic surfaces present to the formation of Dew, that some perseverance is necessary in pursuing the inquiry; and yet the slowness with which they receive moisture, discloses relations infinitely more varied than arise in the better radiators of heat.

(667.) On the same night that Dew is copiously deposited on glass, swansdown, wool, and the grassy

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* There are exceptions, however, respecting some particular hills which merit attention, and require caution in the observer. Dr. Wells remarks, that "in hills which are insulated and of inconsiderable lateral extent, the air surrounding their summits, on nights favourable to the deposition of Dew, is warmer than that at their bases; and hence the superiority of the cold of a low plain from radiation, over that of a wide expanse of hilly ground, will, for obvious reasons, be less; but no superiority of this kind will probably exist in a low plain, when the high ground is not only extensive, but flat on the top, forming what is called table land; unless indeed, which seems to be actually the case, the air of such an elevated country should be commonly more agitated than that of lower places equally level."

Difficulty in obtaining Dew on them.

surface of a field, a polished metallic plate in contact with the grass, may retain its lustre undiminished during the whole time of observation. When indeed moisture is deposited upon metals, it commonly sullies only the lustre of their surfaces; and at times when it is sufficiently abundant to gather into drops, they are generally small and distinct.

Arises from their small radiating powers.

(668.) This slowness of metals to receive moisture from the air, is dependent in the first place on their feeble radiating powers; and, secondly, on their capability of receiving, by aid of their conducting powers, at least as much heat from the atmosphere as other bodies, and more than others from the warmer substances they may happen to touch. Before Dew, indeed, can be deposited on the surface of a metal, it is necessary, not only that its surface should be cooled, but that the whole of its mass should be so lowered in temperature, as to condense the watery vapour, affording thereby another remarkable contrast to the feeble conductors of heat, which gain moisture on their surfaces, even when their parts a very little below are warmer than the air.

Not only the surface of a metal, but the whole of its mass must be lowered in temperature before Dew is formed.

Metallic plate several feet above ground may have Dew on both sides.

(669.) From the same ready passage of heat from one part of a metal to another, arises the phenomenon that a metallic plate suspended in the air, several feet above the ground, is covered with moisture on its lower side, as well as on its upper, and this at a time when the under surfaces of bodies more capable of receiving Dew are without any deposition of the kind.

If in contact with ground, Dew often formed on lower side, while its upper remains dry.

(670.) When a metallic plate, however, is laid upon the bare earth, on a night favourable to the deposition of Dew, moisture will be deposited on its lower surface, at the time the upper remains dry. And the cause of the phenomenon is to be sought for in the under side of the metal partaking of the cold produced by the exposure of its upper side to the clear sky, and thereby condensing the moisture ascending from the warmer earth below.*

Deposition of Dew facilitated by changing position of metal.

(671.) The deposition of Dew on a metallic plate may be facilitated by applying it to different portions of cold grass in succession.

Size of a metal plate influences formation of Dew.

(672.) But the dimensions of metallic plates appear to influence the formation of moisture upon their surfaces. A large metallic plate lying on grass will resist Dew more powerfully than a small one similarly circumstanced. If, however, the two plates be suspended at the same height in the air, the small one will resist the formation of Dew more powerfully than the large. The lesser plate, in the first instance, gains Dew most rapidly, from its relative size permitting a more active exercise of its conducting power, thus enabling it to partake of the diminished temperature of the grass; whereas, in the latter example, the small plate receives, in proportion to its size, a larger share of heat from the atmosphere than the other.

A large metal plate on grass less readily dewed than if raised a few inches above it.

(673.) If a large metallic plate be placed on the grass, it will be less readily dewed than when raised a few inches above it. In the former position, such a plate freely obtains, by its great conducting power, heat from the earth; whereas, when it is suspended freely in the air, it reflects whatever heat may be radiated from the grass below. The grass also will have less heat than when the metal was in contact with it, partly from the small oblique view of the sky afforded to it, and partly from receiving air which has been cooled by passing over other grass fully exposed to the heavens.

Small increase of temperatu in metals sometime causes De to disappe on them.

(674.) As the temperature of metals is never much below that of the neighbouring air, a small diminution of their radiating powers, from any cause, will often occasion the Dew previously formed upon them to evaporate; though other substances, like wool, which had been more cooled by radiation, are still gaining moisture from the air. For a like reason, a metal which has been purposely wetted, will often become dry at night, while other substances are moistened by Dew.

Results o union of good and bad radia tors.

(675.) Having thus briefly treated of the formation of Dew on good and bad radiators, let us next inquire into some of the phenomena resulting from their union. In the first place, a good radiator, as wool, when placed upon a bad radiator, as tin, will, by gaining heat from it, acquire less dew than an equal portion of the same substance laid upon a good radiator like grass. But when the metallic body, having wool in contact with its upper surface, is raised above the ground, the wool will gain more Dew, on account of the metallic surface reflecting the heat which is radiated to it by the warmer grass; thus enabling it to preserve undiminished the cold it acquired by the radiation of the upper surface of the wool to the sky.

Good ra tor attac to bad o checks d position Dew on ter.

(676.) If a metal be closely attached to a substance of some thickness which receives Dew powerfully, the radiation of the metal, instead of being increased from this circumstance, will be diminished, provided the metal covers the whole of the upper surface of the body. And if to the non-metallic side of a piece of gilt paper several wooden letters be attached by means of gum, the portions of the metallic surface not in contact with the letters will be found covered, under favourable circumstances, with minute particles of Dew; while the parts in actual contact with the wood will remain perfectly dry. This experiment, when performed with the letters DR. WELLS, presented the appearance denoted in fig. 23.

Such is the regularity which guides these depositions, that whatever may be the forms of the wood actually in contact with the non-metallic side of the paper, the dry spaces will be rigorously confined to them. Hence we shall find in figs. 24 and 25, that a wooden cross being attached to the former, the dew will be confined to the triangular spaces not in contact with the wood; and in the latter, the triangular areas with wood attached to them, will remain free from moisture, the form of the cross being visible by the innumerable drops that cover it. The same observations apply to figs. 26, 27, 28, and 29. In fig. 30, where the form of the body in contact is more fanciful, the Dew is still confined to the other parts. Fig. 31 represents an interesting example of Dew just beginning to be deposited in small triangular forms, perfectly defined in the corners of the metallic paper; and in well-defined segments in the middle of the sides. Fig. 32 is an example in which these small depositions are more irregular.

Result arising from j tion of metal glass.

(677.) Some very interesting phenomena also result from the junction of a metal with glass. If two watch-glasses, with their concave sides uppermost, be placed on a plate of polished tin, and one of them be surrounded with a ferule of the same metal of the same diameter as the glass, and a depth equal to its versed sine, the following phenomena will be perceived. In the crystal without the ferule, of which a section is represented in

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* Dr. Wells once observed on a cloudy night, a piece of glass laid over an earthen pan containing water, and placed upon the ground, to be wet on its lower side, while the upper was dry; the glass being in this situation sufficiently cold to condense the vapour of water heated by the earth, but not enough to condense the watery vapour of the air.

fig. 33. A zone of moisture will be found to surround the edge, the particles diminishing in size inwards, as denoted in fig. 34. At the bottom a perfectly dry circle will be found. In the other glass, of which a section is denoted by fig. 35, with the surrounding ferule A B, C D, a dry zone will be found to surround the outer edge of the glass, and a dry circular space at the bottom, but a dewy zone, E F G, H I K, will be found existing, as in fig. 36, having large particles in the middle, and others progressively diminishing in size towards both its edges. After these appearances have existed for a certain time, a secondary deposition of moisture, under favourable circumstances, will be found to take place. Within the dewy zone of fig. 34 another very narrow zone of moisture will be formed of exceedingly fine particles, as represented in fig. 37; and on each side of the moistened zone of fig. 36 similar zones may be seen, as in fig. 38. For the cause of these appearances, see vol. xvi. of the *Journal of the Royal Institution*.

Of wafers and glass.

(678.) An example of the regularity with which Dew is deposited round a series of wafers placed upon glass, is given in fig. 39.

Effects of covering glass with a smaller surface of metal.

(679.) Another very interesting experiment may be performed, by partly covering a surface of glass with a smaller surface of metal. On a favourable night, the uncovered portion of the glass will quickly become cold, and derive to itself a part of the heat of the metal. The surface of the metal will hence be more readily dewed, than if the whole exposed surface had been metallic. The actual deposition of moisture, on the two kinds of surfaces, will in such a case be very curious. Of the metallic part, moisture will be first and most abundantly deposited on the outer edge, from its being nearer to the colder glass; while the parts of the uncovered glass, contiguous to the warmer metal, will be the last and least abundantly dewed. Supposing A B C D, in fig. 40, to denote the glass, and E F G H the metal attached to it, an enlarged type of the Dew may be represented as in fig. 41; but a more perfect idea of the whole phenomenon may be gathered from fig. 42, in which the letters composing the celebrated name of LORD BACON are metallic, and applied on a large scale to a surface of glass, according to the conditions of the experiment.

Examples.

Example of conduction checking formation of Dew.

(680.) The following is an example of the effect of conduction in checking the formation of Dew. Fig. 43 represents a plate of iron fastened by screws to the top rail of a gate, of which fig. 44 is a section. The whole of the plate was covered with Dew; but the particles on the heads of the screws and the spaces around them, were the smallest, on account of the heat the screws derived from the internal mass of the wood.

Examples of progressive formations of Dew, and of effects of a gentle current.

(681.) An example of the progressive formation of Dew is given in the different appearances of the word DEW, represented in figs. 1, 2, 3, 4, 5, and 6, plate v; and also in the successive states of the word COLD, in figs. 7, 8, 9, 10, 11, and 12, the latter series exhibiting also the partial manner in which moisture sometimes continues to be deposited during a whole night, in consequence of the action of a gentle current.

Another example of effects of a current.

(682.) Another example of the influence of a gentle current is given in fig. 13, which represents a parallelogram of gilded glass, having its metallic side uppermost. The first deposition of moisture took place at A the leeward end, the Dew gradually advancing thence to the middle of the surface, distinct drops at the same time being deposited at D, B, E, C. As the particles increased in size round the three edges, other minute drops were successively deposited, more distant from them; accumulating, however, with the most rapidity on the leeward sides A and C. After many hours' exposure, an oval portion of the metallic surface was found entirely free from moisture. At the last observation the particles at A had increased to at least an eighth of an inch in diameter; those at C being rather less. The particles at the corners D and E preserved also their superiority in size above those at B.

Examples of deposition of Dew on insides of windows.

(683.) There are some interesting phenomena connected with the deposition of Dew on the insides of windows, which merit notice in this place. At times, and when the window is unscreened by a blind, it assumes forms of very great symmetry, as in figs. 14 and 15; but the effect of a blind is in general to destroy the uniformity which prevails in other cases, as in figs. 16 and 17; while in others, where the blind exerts a less decided influence, some small approach to uniformity may be traced, as in figs. 18 and 19. All these depositions result from the glass being cooled by the external air, and the internal air in contact with it depositing, in consequence, more or less of its moisture. The Dew will be found most copious, where the glass has been screened by a blind or a shutter. Dr. Wells proved, by applying the naked bulbs of two delicate thermometers to a covered and uncovered pane, that the former was three degrees colder than the latter; the air of the chamber being at the same time eleven degrees and a half warmer than that without. Here the closed shutter shielded the glass, which it covered, from the heat radiated to the windows by the walls and furniture of the room, and thus, as Wells remarks, kept it nearer to the temperature of the external air, than those parts could be, which, from being uncovered, received the heat emitted to them by the bodies just mentioned. In the case of an external shutter, the effect will be directly opposite to what has just been stated; since it must prevent the radiation, into the atmosphere, of the heat of the chamber through the glass.

Cause.

Effects of a blind or shutter.

Example of Dew on outside of a window.

(684.) It is not, however, on the insides of windows only that Dew is deposited, it being sometimes formed on their *outsides*. Fig. 20 represents an example of this kind, wherein the portion of the window above A B was covered on the outside with particles of Dew so very numerous, as to prevent objects from being seen distinctly through the glass; but below A B, where the *inside* of the window was covered with a muslin curtain, the particles on the *outside* were much less numerous. In some cases where a pane has been cracked but not broken, a perfectly dry margin on each side of the crack will be found, as in fig. 21, all the remaining parts of the glass being covered with innumerable particles of Dew.

Beautiful formation of Dew on threads of gossamer.

(685.) The formation of Dew on the delicate threads of the gossamer, is worthy of attentive consideration by the accurate observer of Nature. Very frequently detached lines will be found covered with innumerable particles like a string of beads, as in fig. 22; but often masses of web will be found the borders of which are covered with large globules of Dew, as in fig. 23, and their internal parts filled with innumerable threads intersecting each other in every possible direction, and covered with smaller globules, which become at last so small as to elude the eye. Mr. White of Selborne mentions, that he once found the whole face of the country covered with a coat of web drenched in Dew, and as thick as if two or three setting nets had been drawn one over the other.*

General circumstances which appear to influence formation of Dew. Clear weather.

(686.) Our limits will now only permit us to advert to some general circumstances which appear to influence the formation of Dew. In the first place, Dew is never abundant except in clear and serene weather. Some traces of it may, indeed, be met with in cloudy nights, if there be no wind; or notwithstanding the wind, if the weather be clear; but it is never observed to form under the united influences of the wind and a cloudy sky.

Dew may be formed during the whole night.

(687.) After Dew has begun to be deposited, it continues to form during the whole night, if the weather remains equally still and serene. Dr. Wells found, that by placing fresh parcels of wool upon grass every hour, during many suitable nights, and weighing each in succession, that Dew had been deposited upon all. The cause, moreover, is apparent when we consider, that after one volume of air has deposited its moisture, the gentle motion that at all times exists in the atmosphere, even when it is pronounced by ordinary observers to be perfectly calm, must cause some other volume to be translated, containing like moisture with the first; and supposing a motion of this kind to go on, the successive depressions of temperature that take place during the whole night, until the minimum temperature about sunrise is attained, will bring even the masses of air which had previously deposited the moisture permitted by their former temperatures, to discharge other portions, when they become again subjected to an increased cold of the radiating body.

Largest quantities formed between midnight and sunrise.

(688.) Whatever may be the quantity of moisture, however, deposited during an entire night, it does not appear that equal quantities are formed between sunset and midnight, or midnight and sunrise. According to Dr. Wells, more Dew is formed in the latter period than in the former. The conditions of the two are indeed very different. The absolute quantity of moisture existing in the air between midnight and sunrise, must necessarily be less than between sunset and midnight, in consequence of the previous precipitation of a part of it; but during the former interval, the temperature is diminished more than in the interval between sunset and midnight. We are not, however, to suppose that the periods of sunrise and sunset form absolute limits to the deposition of Dew, and accordingly moisture is frequently found on bodies capable of receiving it, both *before* sunset, and *after* sunrise.

Dew is more plentiful in Spring and Autumn than in Summer

(689.) Dew is more plentiful in Spring and Autumn than in Summer; and more abundant after rain than after dry weather. The greatest Dew occurred, during the long experience of Dr. Wells, when the barometer was sinking; and Deluc has observed that rain may be foretold, when Dew is very abundant in relation to the climate and season.* Howard mentions that he has sometimes found Dews so abundant in Autumn, as to be capable of daily measurement in the rain-gauge.

Very copious on nights followed by misty mornings.

(690.) Dew is always produced in great abundance on those clear and calm nights which are followed by misty mornings; and it is also found plentifully deposited on a clear morning succeeding to a cloudy night.

Increase of atmospheri temperatur during day promotes it formation.

(691.) Increase of atmospheric temperature during the day, supposing other circumstances favourable, promotes in a great degree the formation of Dew. The law by which the aerial columns gain moisture, increases more rapidly than that which regulates their temperature; and hence, a small decrease of heat in the air, during the night, must bring it, when the temperature is high, much nearer to a state of saturation, than when the temperature is low.

Gentle motion of air promote its formation.

(692.) A gentle motion in the lower strata of the atmosphere, by bringing fresh volumes of air into contact with the cold surface of the Earth, will produce a more abundant deposition of Dew, than if the atmosphere were entirely calm.

Unequal quantities of Dew may be formed in nights equally calm and clear.

(693.) In nights equally calm and clear, very unequal quantities of Dew may be precipitated. The great inequalities existing in the lengths of the nights in our latitudes, may be referred to as one cause of these differences; but another, and a more fertile cause, is found in the unequal degrees in which moisture exists in the air. At one time it was thought that the cold connected with the formation of Dew, ought always to be proportional to the quantity deposited; but Dr. Wells clearly proves, that the same degree of cold in the precipitating body, and which may take place in nights equally calm and clear, may be attended with much, little, or perhaps no Dew, according to the existing state of the atmosphere with regard to moisture.

Influence of particu lar winds.

(694.) Particular winds have a tendency to promote the formation of Dew in different Countries, from their transporting air highly charged with moisture. In Europe, Southerly and Westerly winds promote it, but Northerly and Easterly winds the contrary. On the Western shores of Africa, Southerly and Westerly winds are favourable to it; but in Egypt and the Barbary States, the North wind brings great accessions of moisture. Dew for these reasons must be more abundant in Norway also than in the Eastern Provinces of European Russia.

Attempts to find annual amount of Dew.

(695.) Various attempts have been made to determine the annual deposition of Dew, but without success. To measure the quantity deposited under the most favourable circumstances, is no easy task; and although Mr. Daniell observes, that the quantity of vapour existing in the atmosphere, in the different seasons, at the level of the sea, seems to follow the course of the mean temperature, such are the varied and uncertain conditions connected with the deposition

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* A phenomenon sometimes mistaken for Dew is often seen on the fine and delicate web of the garden spider. "If you examine," says Kirby, "a newly formed net with a microscope, you will find that the threads composing the outline of the radii are simple, but those of the circles closely studded with minute Dew-like globules, which from the elasticity of the thread are easily separable from each other. That these are in fact globules of viscid gum, is proved by their adhering to the finger, and retaining dust thrown upon the net, while the unadhesive radii and exterior threads remain unsoiled. It is these gummed threads alone which retain the insects that fly into the net; and as they lose their viscid properties by the action of the air, it is necessary that they should be frequently renewed." The beautiful regularity with which these drops are disposed, and their gradual decrease in size as they approach the centre of the web, are worthy of attentive examination.

* *Rech. sur les Mod. de l'Atm.* sec. 725

Estimated annual amount for England.

of Dew, that no very accurate result for the average annual deposit can be obtained in the present state of our knowlege. It must indeed vary with every climate and every locality. In a general way it has been estimated for England at about five inches annually, which is computed to be about a seventh part of the average quantity of moisture received by the atmosphere in the same time. Instruments have been contrived to measure the quantity of Dew deposited at any time, but they are entirely fallacious.

Honey Dew.

(696.) There is a substance called Honey Dew to which we must briefly advert. It is well known to Naturalists that it is not deposited on vegetables by the atmosphere, as its name would seem to imply, but is excerned by insects of the genus *Aphis*, which inhabit the under sides of leaves, and deposit it on the surfaces of those below. This little creature seems to subsist by drawing the juices from the sap vessels, and by a peculiarity of constitution, rejects the richer saccharine part, which afterwards affords nourishment to many other insects. Ants are so fond of it, that a whole colony may be found travelling to the highest branches of a tree in search of it; and they have been seen to seize the clear drop, while yet attached to the body of the Aphis, which, although defenceless, was not molested further by the predaceous wanderers. Honey Dew is sometimes so abundant as to drop from trees.

Wells's Essay on Dew to be highly rated as an admirable specimen of the inductive logic.

(697.) We cannot close this division of our Essay, which we do with reluctance from its very great interest, without recommending most strongly to the reader's attention, Dr. Wells's valuable *Essay on Dew*. We know of no Work in our day which has been more universally admired than the Treatise of Dr. Wells; certainly none that practically exemplifies in a purer and better form the admirable inductive system which it was the object of Bacon to teach.

Hoar Frost.—Ice.

Hoar Frost.

(698.) There are conditions, however, of the atmosphere which sometimes cause dew to be frozen, on whatever bodies it may have been deposited, and such appearances are denominated Hoar Frost. Hoar Frost is formed in England much more frequently than is commonly supposed; and such is its occasional severity, that a single night, even when the warmth of the year would seem to secure us from its rigorous effects, will sometimes destroy all the hopes of the gardener.* For ten months in the year, says Mr. Daniell, vegetation is liable to be affected at night, from the influence of radiation, by a temperature below the freezing point of water;† and even in the months of July and August, which form the only exceptions, a thermometer covered with wool will sometimes fall to 35°. Howard, however, observes that a night on which Fahrenheit's thermometer remains for some hours below zero, hardly occurs in our climate more than five times in a century. In England, a continued Frost may be regarded as an exception to the rule of the climate, and occasionally some winters pass almost without Frost. As might be expected, Frosts generally disappear with a wind from the Atlantic. In Devonshire, three successive frosty mornings are regarded by the farmer as a sure harbinger of rain. The mean temperature of each of three similar periods of Frost, in the long winter of 1813—14, did not vary a degree from the freezing point, although preceded and followed by periods whose mean temperature was 44°; and Howard remarks. that the analogy might be carried even further. The most intense Frosts penetrate but a few inches into the Earth, but the depth must be variable from the diversity in the conducting powers of bodies.

Frequent.

Ten months in the year in England.

A continued Frost rare.

Frosts disappear with a wind from the Atlantic.

Dew must precede the formation of Frost.

(699.) As a deposition of moisture must in all cases precede the formation of Hoar Frost, whatever causes tend to modify in any way the deposition of humidity,—whether they arise from the substances of bodies themselves, the nature of their surfaces, or their textures; from the clearness of the sky, the varied influences of clouds, or from terrestrial objects modifying in some way or other the radiating power,—must in the same degree influence all the phenomena of Hoar Frost. If we take the case of grass, the fibrous texture of which is so favourable to the emission of heat, we shall find a copious radiation continuing, until a temperature at length is reached, equal or below the freezing point of water. The moment at which this happens, will of course vary with the circumstances of climate and of season. At some periods of the year, and in particular localities, it may reach the temperature of thirty-two, early in the evening, or even before sunset; whilst at others it may be protracted till the minimum temperature occurs about sunrise, or not sink to the freezing point at all. Any dew deposited, must hence, when the temperature is low enough, be frozen; and the Hoar Frost which whitens our fields in the morning, may thus have been of longer or shorter duration, according to the season of the year, and the continuance of the proper conditions of temperature during the night. Often, indeed, will the atoms of Dew that have been converted into Hoar Frost during the night, be dissolved again before the morning; and amidst the uncertain fluctuations of our atmosphere, both as regards temperature, aspect, and the variable circumstances of bodies themselves, it is possible to suppose conditions to arise, in which more than one transition of this kind may take place during the night. It should be borne in mind also, that Hoar Frost may be formed when the temperature of the air is above the freezing point of water, since a body may have a temperature at or below thirty-two, when the air around indicates a higher degree of heat. Its continuance, however, under such conditions cannot be very long.

Illustrated in case of grass.

Time of its formation variable.

Dew converted into Hoar Frost, and the Hoar Frost back again into Dew, several times during the night.

Modifications produced by radiation in Hoar Frost.

(700.) It may be useful briefly to advert to some of the modifications which different degrees of radiation produce in the formation of Hoar Frost. Where dew is amply deposited, that is, where radiation has been allowed to disclose its full power, Hoar Frost will be found most abundant. In wide and open plains,—or in those gently sloping grounds, which break only the undulations of the air, without limiting in any way the general aspect of the sky, every blade of grass, in favourable states of the atmosphere, will be found covered with delicate crystals of Hoar Frost. But beneath the branches of a noble oak, where radiation has been checked, this hoary appearance will be dimi-

Checked by trees.

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* On the 6th of May, 1831, the temperature during the night sunk to 20°, at Edmonton. In the morning, the leaves of the vine, the walnut, and the oak appeared shrivelled and black. Their appearance was the same as if they had been burned, and when pressed they crumbled into dust. This temperature was 6° lower than it had fallen in that month, at that place, for forty years.

† In the month of June, a plant may be so circumstanced in this Country, as to undergo all the changes of heat from 154° to 30°.

Examples.

nished; or sometimes a moderate dew may be found in such a situation, while the grassy covering beyond the tree will be entirely frozen. In the fine park of the Earl of Morley at Saltram in Devonshire, we remember on one occasion seeing every tree surrounded as it were with an Oasis of green verdure, of sizes and forms regulated by the spreading branches of the trees, while the other parts of the ground were covered with Frost. A tall, slender poplar had but a small, circular spot surrounding it, whose limits were nearly fixed by the vertical lines A B and C D, fig. 1. plate vi., tangents to the greatest horizontal section of the branches of the tree; while a magnificent oak with its giant arms preserved a large and irregular surface, denoted also by a dotted line surrounding the trunk of the tree, and determined by similar vertical lines, E F and G H, fig. 2. Many interesting phenomena of this kind would be noticed in a woody and enclosed country like fig. 11. plate iv. In some parts, the Frosts would be found much more severe than in others; and where a wide expanse of sky is open in a low situation, there they would be found most intense. Daniell remarks, that the leaves of the vine, the walnut-tree, the succulent shoots of dahlias, and potatoes, are often destroyed by frost in sheltered valleys, while upon surrounding eminences they remain untouched. He has found a thermometer in a valley thirty degrees colder than on a hill. Such effects, however, according to Wells, are limited to hills that are insulated, and of inconsiderable lateral extent.

An enclosed country affords many examples.

Effects of position in influencing the formation of Hoar Frost.

(701.) As an example of the power of position in influencing the formation of Hoar Frost, we select the case of a printed paper, a portion of which, A B C D, fig. 3, was attached to the inclined surface of the coping of a wall, and the remaining part, C D E F, to the vertical surface of the same wall, so that the letters composing one of the words, and which we have here supposed to be METROPOLITANA, were partly on one of these surfaces and partly on the other. One morning, the sloping surface of the paper was found abundantly covered with Hoar Frost, but none was to be seen on the vertical part C D E F; and so well defined were the crystals, that the letters of the words THE ENCYCLOPEDIA, had all distinct groups upon them, separated from the crystals on the white paper, by visible boundaries. In like manner, the *upper* halves of the letters of the word METROPOLITANA were covered with crystals in the same manner as the letters of the word before mentioned; but none were to be seen on their *lower* halves, or on *any* part of the paper bounded by C D E F, the edge of the wall C D seeming to fix a definite limit to the crystalline power.

Example of radiation influencing the formation of Hoar Frost on the railing of a field.

(702.) Another striking instance of the effects of radiation in modifying the phenomena of Hoar Frost, is given in fig. 4, which represents the railing of a field composed of two horizontal rails, with vertical bars at moderate intervals. The upper edge of the rail A B, from being exposed freely to the sky, was found abundantly covered with Hoar Frost; whereas the corresponding edge of the lower rail disclosed rectangular portions only, C D, E F, G H, I K, &c. of Hoar Frost, leaving the alternate spaces D E, F G, H I, almost, if not altogether, free from it. Now, it will be remarked on referring to the figure, that the vertical bars were immediately opposite the last-mentioned spaces, and thus deprived them of the more abundant view of the sky which the others enjoyed. At the same time the whole upper surface of this rail was deprived of its direct radiation to the zenith, which is most effective in lowering the temperature of a body, thus accounting for the smaller sizes of the crystals covering the portions referred to.

Branches o trees and shrubs.

(703.) On some occasions the branches of trees and shrubs illustrate in a very beautiful way the power of radiation. Their upper parts exposed to the sky, discharge their heat rapidly; and hence become covered with an abundance of fine crystals. Where however one branch in any way intercepts the view of another, without being in immediate contact with it, as at A or B, fig. 5, the hoary crystals will be found much less numerous.

A Norway spar.

(704.) Another example bearing on the same inquiry, occurred in the case of a long Norway spar which had been deprived of its bark. It was lying on nearly horizontal ground, and during the night a portion of its surface, E F G H, fig. 6, had been covered with dew. In the morning, from the greater radiation of the upper part of the spar, a uniform portion, A B C D, of about two inches in width, was found covered with the minutest crystals of Hoar Frost; while the equally uniform spaces, A C F E, B D G H, about an inch in width on each side of it, retained their moistened character unchanged.

Check to radiation b coping of wall.

(705.) An interesting fact connected with the same important truth, is recorded in the VIth volume of the *Horticultural Transactions*. In fig. 7, A B C D represents a transverse section of a wall, covered with a coping A B. In the instance of a very severe Frost on the 29th of April, 1826, all the shoots of the vines projecting beyond the perpendicular line A C, that is beyond the salutary influence of the coping, were quite cut off by the frost; but the trees whose shoots did not project beyond that vertical line, were quite protected.

An interposing bod preventing the disappearance of Hoar Fros

(706.) The effect of an interposing body, in checking in some cases the formation of Hoar Frost, becomes of an opposite kind, when from any increase of temperature the Frost begins to disappear. Fig. 8 is an instance where Frost had formed very abundantly on the inside of the glassy surface A B C D. Early in the morning a piece of paper was carelessly placed so as to cover a portion, E F G D B, of the glass, but not in contact with it. In the course of the day, the icy particles covering the space A E F G C were the first to dissolve; and when the whole had become converted into dew, the frozen particles bounded by E F G D B remained, though not so beautifully defined as at first. On the same occasion, a druggist's window exhibited the appearance of fig. 9, the figures of the assemblages of frozen particles being nearly governed by the forms of the glass vessels on the inside.

Examples.

Remarkab phenomen connected with vegetables.

(707.) There are no objects which disclose more remarkable phenomena connected with radiation, than the different tribes of vegetables; and the effects of Hoar Frost upon them are eminently calculated to display its effects. We have before remarked, that every flower has a radiating power of its own, and so we may add has every leaf; differing in different plants, and varying in the same plant from exposure and position. The grasses disclose the same diversity, and while the Almighty seems in consummate wisdom to have adapted every plant, "from the cedar tree that is in Lebanon, even unto the hyssop that springeth out of the wall," to a locality in which the conditions of temperature and atmospheric humidity are best adapted to its general wants; it is worthy of

Tempera-ure and h midity adapted t their gene ral wants.

Radiation necessary for deposition of moisture on plants.

observation, how much an alteration of the circumstances in which Nature originally placed it, seems to affect its energies and growth. "To vegetables growing in the climates for which they were originally designed by Nature," says Daniell, "there can be no doubt that the action of radiation is particularly beneficial, from the deposition of moisture which it determines upon their foliage; but to tender plants, artificially trained to resist the rigours of an unnatural situation, this extra degree of cold may prove highly prejudicial."

Hoar Frost affects parts of the same flower differently.

(708.) The different degrees also in which Hoar Frost affects different parts of the same flower, are worthy of attentive observation. "Upon inspecting the young fruit of such trees as were at the time in blossom," observes Mr. Lindley in allusion to the great Frost recorded in the *Horticultural Transactions*, "it appeared as if no injury had been sustained by their flowers; but upon examining them more minutely, it was found that their ovaria were black with death, and it was subsequently seen that fruit so affected, all fell from the trees and perished." In the blossom of the strawberry, the ovaria were likewise destroyed, but the stamens were little injured, proving that a degree of Frost incapable of affecting the fleshy calyx, and the petals or stamina immediately enclosing it, entirely destroyed the ovarium through all those envelopes. But we can only hint at a subject of boundless interest and extent.

Trees frequently destitute of Hoar Frost when plants nearer the ground are covered with it.

Cause.

(709.) Trees are frequently destitute of Hoar Frost, when shrubs and plants nearer the ground are covered with its forms. Wells has remarked that "the leaves of trees often remain dry throughout the night, while those of grass are covered with dew; and the reason he assigns for the absence of moisture, will, by a simple alteration of the conditions of temperature, account for the absence of Frost. Shrubs and plants, says he, being in a stratum of air of a lower degree of temperature, but of greater humidity than that surrounding lofty trees, the lower stratum also being the most tranquil of the two,—there are causes in activity, more favourable to the formation of dew on plants and shrubs, than on the leaves of trees in the regions of the air above. The diminished temperature, therefore, which converts that dew into Hoar Frost on shrubs, may be insufficient to produce dew on trees; or should dew thus be formed, the greater warmth of the air above may cause it to preserve its watery form. Thus it is, that the diligent and sanguine gardener has often to lament the loss of valuable plants, while trees whose summits are only a few feet higher are entirely unhurt. Protecting plants,* therefore, whether by horizontal or vertical screens, or by an application of straw and mats, becomes an important object in the economy of gardening. Too often, however, the screen or mat is placed in *contact* with the object it is intended to protect; the gardener forgetting that the heat which the screen loses by radiation, is also lost by the tree, from its conducting power.

Appearances of Hoar Frost very beautiful.

(710.) It is remarkable, however, that the appearances of Hoar Frost, so beautiful and so varied, from the pendulous drops which adorn the sharp summits of grass, up to the infinite diversity of forms deposited on glass, should have met with so little attention from Philosophers, and that so few attempts should have been made to describe them. A sheet of common brown paper exposed to a clear and tranquil sky, will, under proper conditions of temperature, be soon covered with innumerable crystals of Hoar Frost, inviting the most delicate examination. A grain of sand will sparkle with innumerable points; while in more complicated formations, all attempts at analysis and description seem lost in the unbounded variety of Nature.

Reduced to three general classes.

(711.) There seems to be three ways in which this process of crystallization goes on. 1. A tendency to freeze the moisture that has been deposited in globules, without any alteration of figure, and denominated by Howard, granular forms. 2. The formation on the fibrous surfaces and edges of bodies, of minute and delicate icicles shooting into spicular forms; and 3dly, those infinitely varied figures, found on flat surfaces, as glass.

Granular forms.

On grass and coarser threads of the spider.

(712.) Granular forms are most generally found suspended from the edges of blades of grass, and sometimes they retain their transparency so completely, as still to resemble dew. In Autumn, the dew deposited on some of the coarser threads of the spider of that season, is found frozen, and arranged like a string of small beads, which may be taken up by the hand.

Spicular variety.

Examples on top of a rude post.

On branch of a tree.

On a tomb-stone.

(713.) The spicular variety is very common, and formed under many diversified circumstances, though the existence of an *edge* seems necessary for its complete formation. Fig. 10 is an example of a rude post in a field, the top of which had been chamfered by the carpenter. On all the edges produced by the chamfering, as A B, B D, D C, C A; E F, F H, H G, G E; A E, B F, D H and C G, delicate and uniform crystals were formed, none of which were confused or blended together. Fig. 11 represents a branch of a tree which had been stripped of its bark. On every fibre there was a line of crystals, and a great uniformity ran through the whole. Wherever the fibres were crooked, the crystals followed them. Fig. 12 is an instance derived from a tomb-stone of a country churchyard, with a long inscription on it, which we have restricted to the memory of PATRICK WILSON.* The whole surface of the stone, from the top to the line A B, was covered with crystals, diminishing in size downwards. The letters of the inscription, however, being cut angularly into the stone, were without any crystals, excepting on their edges, all of which were covered with larger crystals than those found on the surface of the stone; but their size diminished from the upper parts of the letters downwards. Thus in the letters of the word MEMORY, a perceptible difference was to be observed in the crystals at the tops of the letters, and those at the bottom; and so those round the edges of the name PATRICK WILSON, while they decreased in size from top to bottom, were very considerably less than those round the edges of the word MEMORY. A horizontal section of the stone through the latter word

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* In the clear blue sky of the Valley of Chamouni, if the crops should not have ripened towards the end of the season, the peasants make fires of green wood, on the two sides of the enclosing mountain, the smoke of which, uniting in the middle, forms a kind of cloudy canopy, which not only prevents the escape of radiant heat, but increases its intensity, and prevents the formation of Frost.—*Quarterly Review*, vol. xxii.

* Dr. Wells has the following remark, "The last subject which I shall here touch upon, is that of Hoar Frost. This substance has, I believe, from the time of Aristotle, been uniformly, and according to my observations, justly, considered as frozen dew. I shall, therefore, frequently refer hereafter to the experiments of the late Mr. Patrick Wilson of Glasgow respecting it, as if they had been actually made upon that fluid. Indeed, several of my experiments upon dew were only imitations of some which had been previously made upon Hoar Frost, by that ingenious and most worthy man."

A star cut on a village tomb-stone.

Upper and under sides of autumnal leaves.

exhibiting the projecting crystals, is given in fig. 13. A star with which the piety of a villager had caused a humble stone to be adorned, had a most beautiful appearance, but feebly delineated in fig. 14. Here also the upper ray of the star had the largest crystals, and the lower the smallest; while the two horizontal rays had crystals of nearly a mean size. Figs. 15 and 16 are examples of the modes in which Hoar Frost is sometimes deposited on the upper and under sides of fallen autumnal leaves.

On iron railing.

(714.) Dr. M'Culloch has given a very interesting account of a formation of Hoar Frost on some iron railing, illustrated in fig. 17. The crystals were pyramidal, but formed of others so minute and entangled, as scarcely to admit of examination, even with a lens. Their length was about one-sixth of an inch, and their bases about one-thirtieth, which was also their distance from each other. All of them were attached to the edges of the bars, at right angles, according to their lengths, at the same time forming equal angles with the surfaces of the bars. The same arrangement was preserved in all the curvilinear parts of the bars; so that each group or pyramid was invariably placed at right angles to the tangent of the curve at that part, or in the direction of the radius of curvature. Hence it would appear that the effort of each pyramid was to recede as far as possible on each hand, not only from the planes, but from the edge; and thus to attach itself at right angles to the latter. The same effect took place also in the interior as well as in the exterior of the curved parts; and thus the whole, as the Doctor observes, "was ciliated like the leaves of some plants with a regular and beautiful fringed work."

Uniformity of crystals.

(715.) In the more intricate parts of the iron-work, and at the junctions of bars, Dr. M'Culloch found a most admirable uniformity. Where any two edges of a bar met at right angles, the crystals at the apex occupied the direction of the diagonal of the cube formed by the union of the bars; or maintained a distance equally removed from the edge of the joint on the one hand, and from the plane at right angles to it on the other; but the crystals on the two meeting edges nearest the apex, did not immediately assume a rectangular position towards these edges; but diverged gradually in succession from that on the angle, till they took the regular position which they held on the remainder of the edge.

(716.) In the re-entering angles of the joints, the crystal of the angle was in like manner prolonged according to the diagonal of the cube; and the crystals intermediate between that, and those which stood at right angles to the internal edges at a short distance, were so arranged, as to maintain equal distances at their bases, without touching at their summits. Thus, all the crystals *converged* for a short distance round the interior diagonal crystal, as they *diverged* from it on the exterior. Whatever were the magnitudes of the angles, the same law was observed; and in cases where very acute interior angles happened to exist, the crystals became so shortened, to avoid a contact with those on the neighbouring edges, that near the extreme point they vanished altogether. The cause of this repulsive power among all the crystals seems difficult to explain. It will be suggested," says M'Culloch, "that it depends on some electrical condition; but it seems hardly possible to explain how this mysterious agent acts in such a case." Fig. 18 is a section of a bar, the projecting lines at the angles denoting the true positions of the crystals. Fig. 19 is one of the crystals magnified.

Example o conduction checking formation Hoar Fro

(717.) As an example of the effects of conduction in preventing the formation of Hoar Frost, we select the following. Fig. 20 is a representation of some cast-iron railing, with massy stone pillars for a gateway, and buildings forming boundaries to the extreme ends of the railing. During a slight Frost with a fog, Mr. Patrick Wilson remarked, that the bars A, B, C, D, E, and F, were without Hoar Frost from top to bottom, in consequence of the heat gained by conduction from the pillars and walls, and the impediments those bodies afforded to the radiation of the bars. The bars G and H were observed to have only a little on them; but all the smaller bars, from I to K and L to M, had their edges beautifully fringed with Hoar Frost, and their flat surfaces also, to within twelve inches of their lower ends. The larger bars were less decidedly covered with Frost, and free from it, much higher above the parapet, as N O, P Q, than the smaller ones.

Probable cause of great dive sity in thi variety o glass.

Several example

Appear of print letters throug some st like pa ticles.

(718.) The great diversity of form in the third variety, of which the most beautiful examples are to be found on glass, results, according to a Memoir of Carena contained in the *Mémoires de Turin* for 1813 and 1814, from the interruptions which the natural force of crystallization undergoes, from the numerous and varied resistances which the surface of the glass presents, and from its imperfect and irregular conducting power, which impresses upon the condensed vapour, the instant before crystallization begins very diversified motions,—sometimes of a rectilinear and sometimes of a curvilinear kind. These diversities of form are most abundant, when the atmosphere is highly charged with moisture and the depression of temperature is very great; and it would seem in many cases as if they resulted from successive depositions,—an effect of alternate states of temperature. We have given a few sketches in figs. 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10, some of which are distinguished for their beauty, particularly figs. 8, 9, and 10. Fig. 11, affords an example of the lower part of a pane covered with one uniform sheet of Frost, the upper edge being bounded by innumerable crystals of a fern-like appearance. Above these were others resembling leaves, of which enlarged representations are given in figs. 12, 13, and 14. Fig. 15 is a view of the diversified crystallizations on different panes of the same window. Fig. 16 is an instance where the deposition of separate star-like particles had been confined from some cause to a part only of a pane of glass, on the inside of which an advertisement had been previously placed, and which we shall here suppose to have contained the word **FROST**. The glass opposite the letter F and part of the letter R was entirely free from Hoar Frost; but the remaining portion of the R, and the other letters, exhibited the appearance in the diagram.

Hexah prisms glass.

(719.) M. Hesell once remarked a layer of ice on his window a quarter of an inch thick, which covered the lead as well as the glass. Instead of presenting the usual vegetative appearance, it was composed of a multitude of crystals more or less perfect; but many exhibited the forms of hexahedral prisms, having their axes perpendicular to the glass.

Air so times l with p cles of ing w

(720.) Howard remarks, that the air is sometimes loaded with particles of freezing water, such as in a higher region would produce Snow. These attach themselves to all objects, crystallizing in the most regular and beautiful manner. A blade of grass under circum-

Appearance of them on grass and shrubs.

stances of this kind, becomes converted into a pretty thick stalagmite. Shrubs covered with spreading tufts of crystal, look as if they were in blossom; while others, more firmly incrusted, appear like gigantic specimens of white coral. The leaves of evergreens are found with a transparent varnish of ice, and a delicate white fringe around. On such an occasion, the whole face of Nature seems dressed out in Frost work. Lofty trees covered with Frost, when viewed against the blue sky, in the sunshine, present a very magnificent appearance.

Freezing mists, called Rime.

(721.) Sometimes, during the existence of a mist, the temperature is so much diminished, as to cause a peculiar crystallization from the freezing mist, denominated Rime. It is most abundantly formed on surfaces opposed to the wind. Howard mentions a case, wherein the melted rime descended in showers from the trees; and there was enough on his rain gauge to produce 0.02 inches of water when melted. Freezing mists are common to the high lands of Tweedale and Lanarkshire. In August 1784 the whole barley crop was destroyed there by a creeping mist of this sort. Their influence is confined to the spot on which they rest. Hence one half of a field is often destroyed, while the other remains safe. From a knowledge of the locality of their effects, attempts have been made, though without success, to disturb these frozen mists, and to save the barley and oat crops, by dragging something over them before sunrise, to shake off the "Rime or Cranreuch." Sometimes the uppermost grains of the oats only are destroyed, the grains below ripening well. But even then the barley was totally destroyed.

Locality of their effects.

Surface of water itself loses heat by radiation and becomes frozen. Point of maximum density.

(722.) At the same time that Hoar Frost is formed in all the abundant varieties we have explained, by the cooling of the surfaces of bodies, and the actual deposition of moisture on them from the air, the surface of water itself, enjoying as it does so high a power of radiation, must have its temperature reduced, and when that depression is sufficient, it must become converted into Ice. The cooling of water has, moreover, a remarkable peculiarity, its density increasing until a maximum is reached at about 39°.5, below which the opposite law of dilatation begins.* As soon, therefore, as a copious radiation from the surface has lowered the temperature of the whole watery mass to the point of maximum density, the upper stratum, by further cooling, must become specifically lighter, and remaining on the surface, be at length converted into Ice.

Formation of Ice may be checked by diminishing radiation.

(723.) The formation of Ice, however, may be checked by any cause which diminishes radiation. Mr. Scott remarks, in the VIIIth volume of the *Edinburgh Journal of Science*, that a turban suspended across an Ice-pit, three feet above the pans, prevented the formation of Ice in those immediately below it; and in several which it only partially covered, Ice was formed on the half of the water, out of the perpendicular line, while that immediately under the turban remained fluid. Two strings, crossing each other at a less height above a pan, divided the Ice into four corresponding parts. These results must of course depend on circumstances of temperature; for if the degree of heat be rather lower than is necessary to freeze water, when no impediment to radiation exists, the whole may become frozen, although partially covered. On the other hand, should the temperature be just sufficient to freeze water under conditions the most favourable, the contents of a vessel, not fully exposed to the sky, may remain fluid throughout. It is to be observed also, that Ice is chiefly formed in Bengal,* when the temperature of the air is above

Formation of Ice in Bengal when temperature is above 32°.

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* "Had water," says Dr. Ure, "resembled mercury, oils, and other liquids, in continuing to contract in volume by cooling, till its congelation commenced, the incumbent cold air would have robbed the mass of water in a lake of its caloric of fluidity, by unceasing precipitation of the cold particles to the bottom, till the whole sunk to 32°. Then the water at the bottom, as well as that above, would have begun to solidify, and in the course of a severe winter in these latitudes, a deep lake would have become throughout a body of Ice, never again to be liquefied. We can easily see, that such frozen masses would have acted as centres of baleful refrigeration to the surrounding Country, and that under such a disposition of things, Great Britain must have been another Lapland. Nothing illustrates more strikingly the beneficent economy of Providence, than this peculiarity in the constitution of water, or anomaly, as it has been rather preposterously termed. What seems void of law to short-sighted man, is often, as in the present case, the finest symmetry, and truest order."

* The formation of Ice in Bengal is so peculiarly interesting, and has led to so many mistaken views, that we are sorry we can only briefly allude to it in a note. According to Sir R. Barker, excavations thirty feet square and two feet deep are formed in a large open plain, their bottoms being covered with sugar-cane, or stems of Indian corn, dried, to the thickness of eight inches or one foot. On this layer are placed, in rows near to each other, small unglazed earthen pans, one-fourth of an inch thick, and one inch and a quarter deep filled with boiled soft water. The pans are sufficiently porous to allow their outer surface to appear moist, after water is poured into them.

In the process carried on by Mr. Williams, three hundred persons were employed. A piece of ground of about four acres, nearly level, was divided into portions of from four to five feet square, and these were surrounded by little mounds of earth, four inches high. In these inclosures, previously filled with dry straw, or sugar-cane haum, were placed as many broad, shallow, unglazed earthen pans, containing unboiled pump water, as they would hold. In the morning, between five and six, a thermometer with its bulb naked, placed on the straw, amidst the freezing vessels, was never found lower than 35°; and he has observed ice, when a thermometer so placed was 42°. Another thermometer, suspended five feet and a half above the ground, was commonly 4° higher than that among the pans; and hence it is possible, Mr. Williams may have seen Ice a little before sunrise, when the temperature of the air was 46°.

Mr. Scott, however, remarks, that porous pans are not necessary for the success of the experiment, and the natives use them only because they have no better; and so well are they aware that the porosity of the vessels is of no advantage, that they usually rub them with grease in order that they may more easily extract the Ice. Mr. Scott has also found by repeated experiments, that Ice may be produced, although a thin film of oil be spread over the surface of the water; the latter being contained in *glazed* plates, which indeed answer much better than the porous pans of the country, the Ice in them being invariably thicker, and the water, when it does not actually freeze, somewhat colder than the similar contents of porous pans placed in exactly the same situation.

Dr. Wells, in repeating the experiment in the way employed by Sir R. Barker, found at one o'clock in the morning of the 4th of May, Ice appear in watch-glasses placed on a grass-plot and on a raised board thinly covered with sand, the temperature of the air, as measured by a naked thermometer, being then, at four feet above the ground 39½°, and at seven feet, 40½°. At two A. M. Ice was observed in the pans in the pit, while a thermometer in the air, two and a half feet above the ground, was 36½°. Shortly afterwards, Ice began also to form in the pans upon the grass-plot. The temperature of grass, fully exposed to the sky, was at the same time 30°, while that of the Earth, an inch below the bottom of the grass, was 45°. During the time of these observations, Dr. Wells informs us, dew formed copiously.

In another experiment performed on the evening of the 22d of May, in the manner described by Mr. Williams, Dr. Wells found water in a watch-glass placed upon straw frozen, after an exposure of little more than an hour, the temperature of the air two feet above the straw being 37°. In half an hour more, Ice began to appear in some earthen pans. In another experiment, Wells placed upon the straw bed, a dry earthen pan, which in the course of the night became covered with moisture, and at length by a further depression of temperature converted into a film of Ice.

And as a beautiful experiment to prove that water may not only freeze at night, in air of a temperature higher than 32°, and at the

32°, on the clearest and calmest nights, which are precisely the conditions most favourable to the formation of dew; the interposition of clouds or the action of the wind preventing its formation altogether.

Experiments of Leslie.

Description of process of freezing.

(724.) Leslie, in his experiments on artificial congelation, has had abundant opportunities for tracing the process by which water becomes crystallized. "When the frigorific action," says he, "is most intense, the congelation sweeps at once over the whole surface of the water, obscuring it like a cloud. But in general the process advances more slowly; bundles of spicula, from different points, sometimes from the centre, though commonly from the sides of the cup, stretching out and spreading by degrees with a sort of feathered texture. By this combined operation, the surface of the water soon becomes a uniform sheet of Ice. Yet the effect is at times singularly varied; the spicular shoots, advancing in different directions, come to inclose, near the middle of the cup, a rectilinear space, which, by unequal though continued encroachment, is reduced to a triangle; and the mass below being partly frozen and expanded, the water is gradually squeezed up through the orifice, and forms by congelation a regular pyramid, rising by successive steps; or if the projecting force be greater, and the hole more contracted, it will dart off like a pillar. The radiating or feathered lines which at first mark the frozen surface, are only the edges of very thin plates of Ice, implanted at determinate angles, but each parcel composed of determinate planes. This internal formation appears very conspicuous in the congealed mass which has been removed from a metallic cup, before it is entirely consolidated.

(725.) "When very feeble powers of refrigeration are employed, a most singular and beautiful appearance is in course of time slowly produced. If a pan of porous earthenware, from four to six inches wide, be filled to the utmost with common water, till it rise above the lips, and then be planted above a dish of ten or twelve inches diameter, containing a body of sulphuric Acid, and having a round broad receiver passed over it; on reducing the included air to some limit between the one-twentieth and the one-fifth part of its usual density, according to the coldness of the apartment, the liquid mass will, in the space of an hour or two, become entwined with icy shoots, which gradually enlarge and acquire more solidity, but always leave the fabric loose and unbroken below. The icy crust which covers the rim, now receiving continual accessions from beneath, rises perpendicularly by insensible degrees. From each point on the rough surface of the vessel, filaments of Ice, like bundles of spun glass, are protruded, and forming in their aggregation a fine silvery surface, analogous to that of fibrous gypsum or satin spar. At the same time, another similar growth, though of less extent, takes place on the under side of the pan, so that continuous icy threads might appear vertically to transpierce the ware. The whole of the bottom becomes likewise covered with elegant icy foliations. Twenty or thirty hours may be required to produce these singular effects; but the upper body of Ice continues to rise for the space of several days, till it forms a circular wall of near three inches in height, leaving an interior grotto lined with fantastic groups of Icicles." Fig. 17 is borrowed from Leslie to illustrate the general appearance of these phenomena.

Examples crystals.

(726.) The small, triangular, needle-shaped crystals, frequently remarked at temperatures but little below the freezing point, are represented in figs. 18 and 19, the latter denoting a more advanced stage of their formation. Their uniformity is shown by the tendency they have to unite under angles of 60°, or its supplementary number 120°. Dr. Clarke observed water to crystallize in regular rhomboids, having angles amounting to the last-mentioned numbers. On a thaw taking place the crystals preserved the same constant inclination of their planes. In the subterranean glacier of Foudeurle, hexahedral prisms of Ice, secondary forms of the crystal, were found. When a thaw is going on, we sometimes find thin sheets of Ice reduced in vessels of still water to forms resembling branches of fern, as in figs. 20, 21, and 22.

Beautiful forms disclosed by Ice when thaw take place.

Effects of fissures a rents in I

(727.) On the American lakes, and even on narrow rivers, fissures and rents of enormous magnitude are often made in the Ice, and are always accompanied with loud reports, like those of cannon. On the return of warm weather, before the Ice melts, the fissures close, and sometimes the edges of them even overleap each other.

Ice at bot tom of rivers.

(728.) The phenomenon of Ice at the bottom of rivers is one of very great interest. Mr. Knight discovered some in the River Teme, in Herefordshire, which he has described in the *Philosophical Transactions* for 1816. On a morning succeeding an intensely cold night, the rocky bed of the river appeared covered with frozen matter, which reflected a kind of silvery whiteness, and which upon examination was found to consist of numerous frozen spiculæ, intersecting each other in every direction, but not assuming anywhere, excepting near the shore, the state of firm compact Ice.

Different opinions.

Radiation and eddie seem ade quate to count for

(729.) A variety of opinions have been advanced respecting the origin of Ice in a situation so different from its ordinary state, and so contrary to what might be anticipated from its known Specific Gravity. The ordinary laws of radiation, joined to the eddies and gyrations of the running streams to which it is peculiar, seem adequate, however, to account for its formation. On the occasion which afforded Mr. Knight the opportunity of examining this phenomenon, the temperature of the surface water was just at the freezing point, small pieces of Ice being every where formed upon its more stagnant parts near the shores; and upon a mill-pond just above the shallow streams, in the bottom of which the Ice had been formed, millions of small frozen spiculæ were floating. At the end of this pond, the water fell over a low weir, and entered a narrow channel, in which its course was obstructed by points of rocks and large stones. Here numerous eddies were formed, which drew the frozen spiculæ under water, as in a vortex. Mr. Knight found these frozen spiculæ to accumulate most abundantly upon such parts of the stones as stood opposed to the current, wherever it was not very rapid, below the little falls, or most rapid parts of the river. Upon some large stones near the shore, of which parts were out of the water, and upon pieces of native rock, under similar circumstances, the Ice beneath the water had acquired a firmer texture, but appeared, from its whiteness, to have been first formed of congregated spiculæ, and to have

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same time gain an accession of weight, by humidity condensed from the air, Wells exposed water until it was cooled to 34°, of this he put twenty ounces into each of two China saucers, which had also been exposed to the air, and then placing the saucers upon the bed of straw. In the morning, a thin cake of Ice was found in both saucers, one of which had gained two and a half and the other three grains in weight. The deposition of dew was found to have been copious.

subsequently frozen into a firm mass, owing to the temperature of the stone or rock. Ice of this kind extended in a few places eighteen inches from the shore, and lay three or four inches below the level of the surface of the water, and did not dissolve nearly so rapidly as that deposited upon stones more distant from the shore.

Ice in Polar Regions results from freezing of fresh and salt water.

(730.) But the great seat of Ice is in the Polar Regions, and the immense depositaries there found, owe their origin to two very different sources,—the congelation of *fresh* and of *salt* water. So early as August, snow begins to fall, and the abundant formations of a Polar Winter, will again be partially melted by the transient vigour of the Summer Sun. The clear water resulting from the dissolution, by descending from all the higher parts of the land, will be collected along the shores, and in the deep bays which more or less fringe the inhospitable coasts. In those succeeding Winter, this water, governed by the ordinary laws of crystallization, becomes frozen; and as year after year, the same circle of changes goes on, the increment, however feeble, must, in the long lapse of Ages, produce masses of enormous magnitude and grandeur. It is remarkable, however, that the formation of these stupendous blocks, should take place in a locality, where powerful causes are in operation to prevent their unlimited increase. The action of the sea, whether silent and unobserved, or whether disturbed by the fury of the Polar winds, must gradually undermine the Icy mountains, until large avalanches descend into the abyss below.

Formation of Icebergs.

Freezing of salt water.

(731.) Sea water, on the contrary, is incapable of producing masses of this kind; nor does the crystallizing power begin, until the temperature has sunk five degrees below the freezing point of fresh water. Such a depression of temperature, however, soon takes place on the decline of Summer; and in a single night, a wide expanse of sea becomes frozen. As the Winter advances, the depth of this Ice is increased to several feet. On the return of the Solar rays, the icy floor gradually melts, and the swell of the Ocean breaks up the enormous fields into fragments, which rapidly disappear. This commonly takes place in June. The Ice from salt water differs in many very remarkable points from that produced by fresh water. While the latter is hard and pellucid, the former is whitish, porous, and almost opake. The difference in their Specific Gravities also is so great, that while the Saline Ice projects only one-fiftieth part above the surface, the Fresh-water Ice is raised one-tenth.

Different appearances of Ice of fresh and salt water.

Limits to indefinite increase of Ice in Polar Regions.

(732.) Nature appears to have set some bounds to the unlimited increase of Ice in the Polar seas. The formation of Icebergs is one powerful cause, and there are probably others in activity tending to the same end. The quantities formed in different years, may indeed be very unequal, but there seems something like a mean limit, between which the oscillations are performed. Meteorology is not sufficiently advanced to disclose this fact, but we may gather it from the memorials of Astronomy. "A continued accumulation of Ice," says Leslie, "would have occasioned a prolongation of the day;"* whereas we know that, from the time of Hipparchus, the duration of the Earth's rotation has not changed a single second in a year.

Mists and Fogs.

Causes.

(733.) Mists and Fogs owe their origin not only to the simple humidity of the air, and to the unequal temperature of its different masses, according to the theory of Hutton before explained, but also occasionally to the union of the vapours arising from the Earth and from marshy plains, the enormous combustion of coal and gas, and other causes of a like kind.

Application of the theory of Hutton.

(734.) In considering humidity alone as a cause of Mists, the examples best calculated to explain them are to be found in those peculiar to rivers.

(735.) The general surface of the Earth, as we have already seen, loses heat by radiation, as soon as the Sun disappears, but the land and water cool in very different degrees. The cooling of the land is limited to the surface, and transmitted but slowly to the interior; whereas in water of a temperature higher than 45°, the upper stratum, as soon as it is cooled, whether by radiation or evaporation, must sink in the mass of fluid, and its place be supplied by warmer water from below; and till the temperature of the whole mass is reduced to the point of maximum density, the surface cannot be the coolest part. Hence it follows, that wherever water exists in considerable masses, and has a temperature nearly the same as the land, or only a few degrees below it, and above 45° at sunset, its surface during the night, in clear and serene weather, will be warmer than that of the contiguous land; and the air above the land will become colder than that above the water; and when they both contain their due proportions of aqueous vapour, and the situation of the ground is such as to permit the cold air from the land to mix with the warmer air above the water, Mist or Fog will be the result. The density of such Mist or Fog will, moreover, be greater as the land surrounding the water is higher, and its depth and temperature greater. These views, first given by the late Sir H. Davy in the *Philosophical Transactions* for 1819, afford, by the experimental evidence on which they are grounded, another strong and convincing proof in favour of the theory of Dr. Hutton.

Views of Sir H. Davy.

Mists on the Danube.

(736.) On the 9th, 10th and 11th of June, the illustrious Chemist just adverted to, found, that the appearance of Mist above the Danube in the evening, uniformly coincided with the diminution of the temperature of the air from three to six degrees *below* that of the river; and the disappearance of Fog in the morning, as constantly resulted from the elevation of the temperature of the air *above* that of the river. Below Passau, where the Danube is joined by the Inn and the Ilz, the temperatures of the three rivers, at six A. M., were respectively 62°, 56°.5, and 56°, the temperature of the atmosphere on the banks, where the three streams mingled, being 54°. At that moment the whole surface of the Danube was covered with a thick Fog; the Inn had a slight Mist, and the Ilz a haziness, indicating the liberation of only a small quantity of moisture. About 100 yards below the place where the three rivers joined, the temperature of the central part of the Danube was 59°, and there the quantity of Mist was less than on the bed of the Danube before the junction; but half a mile lower, the warmer water had again found its place at the surface, and the Mist was as copious as before the union of the rivers.

(737.) Similar results were obtained by Davy in passing along the Rhine from Cologne to Coblentz, on

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* *Edinburgh Cabinet Library. Polar Seas and Regions,*—an interesting and valuable Work.

Mists on the Rhine and other rivers.

Mists on the Tamar.

the Raab, near Kermond in Hungary, in July; on the Save, in Carniola, in August; on the Ironzo, in Friuli, in the middle of September; on the Po, near Ferrara, in the end of September; and repeatedly on the Tiber, and on the small lakes in the Campagna of Rome, in the beginning of October; and he remarks, that in no instance was Mist formed on a river or lake, when the temperature of the water was *lower* than that of the air, even when the atmosphere was saturated with vapour. An example tending to confirm these results, occurred on an excursion to the Morwell Rocks on the river Tamar. The river near that place is exceedingly circuitous, and it was remarked, that the Mist accommodated itself to all the turns and windings of the channel; thus affording an instance of the well-defined limits which proper circumstances of temperature impart. An attempt to represent this very interesting appearance has been made in fig. 1. plate viii. The following observations were made at the time.

Time.	Temperature of the River.	Temperature of the Air 6 feet above the River.	Mean Temperature of the Land on the borders of the River.	Temperature of the Air 6 feet above the Banks.
August 27th, 9 P. M.	56°	47½°	45°	49°

Limits of Mist confined to surface of the stream.

Mist exhibited appearance of pure wool.

(738.) These temperatures confirm in every way the views of Davy. The warmth of the water being greater than the air above it, was the cause why Mist was formed on the river; and the temperature of the banks being below that of the air which covered them, was also the reason why the limits of the Mist were confined to the actual surface of the stream. Fig. 2 is an example which confirmed the same fact; but the sketch is intended only to illustrate the upper boundary of the Mist above the trees, and which seemed as if formed of enormous packs of pure wool. The same beautiful whiteness was perceptible between the trunks of the trees, and formed a fine contrast to the Autumnal foliage.

Increase depends on continued action of first cause of radiation of heat from particles of water composing the Mist.

(739.) After Mists have been formed above rivers and lakes, their increase seems to depend not only upon the continued operation of the cause which originally produced them, but likewise upon the radiation of heat from the superficial particles of water composing the Mist. This cause must produce a descending current of cold air in the very body of the Mist, whilst the warmer water continues to send up vapour.

Cause of Mists rising above surrounding hills.

(740.) It is to the same circumstance also, that the phenomenon must be ascribed of Mists from a river, or lake, sometimes rising considerably above the surrounding hills. Sir H. Davy often witnessed this appearance during the month of October, after clear and serene nights, in the Campagna of Rome above the Tiber, and on Monte Albano, over the lakes existing in the ancient craters of that extinguished volcano. In one instance indeed, on the 17th of October before sunrise, the atmosphere being entirely calm, a dense, white cloud of a pyramidal form was seen on the site of the Alban Lake, rising far above the highest peak of the mountain. Its form gradually changed after sunrise, the summit first disappearing, and the whole body at last melting away in the sun beams.

Mists rarel form upon rivers springing from rock having mean tem perature c climate.

(741.) In cases where rivers springing from the interior of rocks, or strata, have the mean temperature of the climate in which they are found, Mists can rarely form upon them, excepting early in Spring, late in the Autumn, or during the Winter. In passing across the Apennines, the 1st, 2d, and 3d of October, Davy observed the beds of all the rivers in the valleys filled with Mist, morning and evening, excepting that of the Clitumnus near its source, which is a limestone bed; and when he examined it at 6½ A. M., on the day last mentioned, its temperature was found 7½° lower than the air.

Current of dry air passing across a riv prevents Mist.

(742.) Great dryness in the air, or a current of dry air passing across a river, will prevent the formation of Mist, even when the temperature of the water is much higher than the air. Thus on the 14th of June, near Mautern, though the Danube at five in the morning indicated 61°, and the atmosphere was 7° less, no Mist was perceived; but at the time of observation, a strong and very dry Easterly wind prevailed.

Mists foun in mornin when diffi ence of te perature o air and water amounts only to on degree.

(743.) It may be proper to add, that Mists are sometimes found in the morning, when the difference in the temperatures of the water and the air amounts only to a single degree, although to produce it, according to Sir H. Davy, the air must be cooled from three to six degrees *below* the temperature of the water.

Depositio of dew mu always pr cede Mist

(744.) The deposition of dew on land must always precede the formation of Mist on water. Suppose at some moment an equality of temperature to take place between the land, the water, and the air reposing over each. When the process of cooling commences, the former will *first* have its temperature reduced below that of the air; and although by this diminution the equality of temperature between the two volumes of air will be destroyed, and a condition favourable to the formation of Mist be created, still, as the cooling of the first volume and the mingling of the two are not contemporaneous, dew will be first deposited.

Rapid fo mation o dew favo able to qu formatio Mist.

(745.) In proportion, however, as the land radiates freely, with the same rapidity must the temperature of the superincumbent air be diminished, and the equilibrium between it and the atmosphere hovering over the water be disturbed. The rapid formation of dew is therefore accompanied by circumstances favourable to the quick formation of Mist; and it hence becomes probable, that, under such conditions, Mist will be formed at an earlier period of the night than when the land radiates less copiously, and dew,—the moisture in the air remaining the same, be deposited in less abundance.

Effect of clouds.

(746.) If in consequence of the interposition of clouds, the cooling of the land and water should be checked, and an equality of temperature be restored between the two masses of air, and the bodies on which they respectively repose, the deposition of dew will be suspended, and likewise all tendency to the further formation of Mist. The entire dissipation of the latter also may result from the change.

Dew an Mist ar formed former of nigh and bot disappe before mornin

(747.) It is sometimes the case that dew and Mist are both deposited in the former part of the night, and both disappear before morning; or, the former may be preserved, and the latter dispersed. The first of these phenomena may occur, when a portion of the night, favourable both to the formation of Mist and dew, is succeeded by a brisk wind; and the second, when by the interposition of dense clouds, the temperature of the land, and the atmosphere over it is raised, so as to render the latter equal or superior in temperature to that of the air over the water, thereby causing the Mist to disappear, from the increased capacity of the air for vapour. This latter circumstance will moreover account for the dispersion of Mists in the morning, before the disappearance of dew.

Mists in Ceylon of great density.

(748.) Dr. Davy, in his Work on Ceylon, remarks, that in the deep, moist valleys among the mountains of that island, Mists are very often formed of astonishing density, and resemble an expanse of water so much, that, to a spectator in the clear, cool air on a mountain above, were he ignorant of the features of the country, they would appear to be real lakes. Occasionally after sunrise, these Mists, formed in the higher mountain hollows, are displaced by the wind, and poured in immense volumes down into the warmer valleys, producing a sudden chill, and a disagreeable humidity of the air.

Arctic Regions peculiar abode of Mists.

(749.) But the Arctic Regions seem the peculiar abode of Mists and Fogs. Before the end of June, the shoals of ice covering those inhospitable regions, are commonly broken and scattered, the temperature of the Ocean being greater than that of the frozen masses. The cooling influence of these masses, in consequence of their elevation above the sea, will be diffused, not only by radiations from their upper surfaces to the sky above, but also by horizontal radiations to the air surrounding their sides; and so powerful are those radiations, that "navigators generally feel a cold stream of air from an iceberg long before it is seen."* A volume of the atmosphere, therefore, between two neighbouring masses of ice, must necessarily have its middle portion of a higher temperature than that of either of the portions of air between it and the icebergs;† and the consequence of such an unequal distribution of temperature must be, to cause the cold air to mingle with that of a higher temperature, and thus to produce Mist or Fog.

Horizontal radiation of icy masses.

Effects on intervening air.

Elevation of these Mists regulated by icebergs.

(750.) The elevation of these Mists above the surface of the sea will also be regulated by that of the icebergs near which they form; since the cooling influence of the frozen masses, by its rapid diminution above their summits, will as rapidly destroy all tendency in the atmosphere reposing on them to assume a condition favourable to Mist. A limit is thus prescribed to the elevation of Mists, governed by the height of the icebergs near which they are formed. Accordingly, Captain Ross remarks, "that the Fog was extremely thick on the surface of the sea, but at the mast head, and at the top of the iceberg, it was perfectly clear." Mr. Scoresby also, in his Paper on Fogs, read before the Wernerian Society, alludes to their definite elevation, and to the sky above being perfectly clear.

Fogs surround Terra del Fuego.

(751.) Fogs of great density prevail also in the sea which surrounds Terra del Fuego. Don Antonio de Ulloa says, in his Letter to Marian, that in sailing round Cape Horn, he found only a few moments when he could obtain a slight glance of the sky. It must not be inferred, however, from hence, that Fogs *constantly* prevail in those regions.

(752.) Van Mons, in his interesting Paper on Mists, (*Nouv. Mémoires de l'Acad. Roy. des Sciences et Belles Lettres de Bruxelles*, tom iv. p. 371,) divides them into dry, humid, and mixed. Dry Mists are either sweet scented, or have a fetid smell. The odour of dry, white Mists, however, is very different from that of coloured Mists. Dry Mists are either white, bluish, dusky-brown, or lilac. The deeper their colour, the stronger is their odour.

Mists in Belgium, dry, humid, and mixed.

Odour of Mists.

Colours.

Humid Mists of two kinds.

(753.) Humid Mists are either visible or invisible, and moisten all bodies. Visible humid Mists, without being odorous, are cold. Invisible humid Mists are not odorous.

Mixed Mists of various kinds.

(754.) Mixed Mists are of various kinds. Some arise from a mixture of two dry Mists, others from a humid Mist mingled with one of a dry kind. Van Mons thinks there is never a junction of an invisible humid Mist with one of a dry kind. Mixed Mists retire successively, one of the two disappearing after the other. They are moist and fetid at the same time.

(755.) A visible humid Mist mingled with a dry Mist of a white kind, produces one of a yellowish colour. This colour is most remarkable by night.

Dry and fetid Mists with Easterly winds.

Odorous Mists with a North wind.

(756.) These remarks apply to the phenomena of Mists in Belgium. Dry and fetid Mists occur there during Easterly winds, and Mists simply odorous during a North wind. Their appearance seems confined to particular localities, and masses may be observed at intervals from each other, in the direction of the wind. Fetid Mists are most frequent there in Spring and Autumn, and at the approach of the solstices, though they may be remarked at all seasons.

Their localities.

Fetid Mists disappear towards noon.

(757.) Fetid Mists, though often appearing in the morning and evening, generally disappear towards noon. When Mists occur in the elevated parts of the atmosphere, their colour becomes sensible before their odour. They are seen thus suspended for a day or two.

Indications of Mists.

(758.) In Belgium, a fetid Mist in Spring or in Summer indicates a dry and hot season. In Autumn it presages storms, and in Winter hard frost.

Dense Fogs common to large towns. Examples, London, Amsterdam, and Paris.

(759.) Dense Fogs seem common to large cities, and have been remarked in Winter, in perfectly calm weather. On the 16th of January, 1826, a Fog was so great in London, that no part of St. Paul's could be seen from the Western railing. The city presented a scene of desolation, and all the manufactories and shops employed their full complement of lights. Trade was universally interrupted. At the time this occurred, the environs of the city enjoyed a beautifully clear sky. In the great Fog which happened at Amsterdam on the last day of the year 1790, the people ran against each other, even though they had lights in their hands. Two hundred and thirty persons were drowned by falling into the canals. Their cries were heard, but people were afraid to advance to their relief. At Paris on the 12th of November, 1797, a great Fog commenced in the afternoon. The obscurity was so great, that persons lost their way completely in the streets, as if they had been blind. It was necessary to be near a very brilliant light, to perceive a faint trace of it. Fourcroy, who described this extraordinary Fog in the *Journal de la Société des Pharmaciens de Paris*, states that it showed itself in spiral groups like cork-screws, and that it had a remarkable taste.

Simultaneous appearance of Fog in different cities.

(760.) The appearance of Fogs in different cities is frequently simultaneous. At the time a great Fog prevailed in London, Dublin was enveloped in one of equal density. Fogs have been known also to precede a

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* *Quarterly Review*, No. xxxvi. p. 448.

† If the water in the vicinity of the icebergs presents considerable inequalities of temperature, the air which reposes on it must be subject to like variations. Captain Franklin remarks, that "the temperature of the surface water was 35° when among the ice, 38° when just clear of it, and 41°.5 at two miles distant;" and there are differences of temperature here sufficient to form Mist abundantly.

strong Westerly wind at Manchester, London, and Paris, and by nearly the same short interval of time at each station.

Cause of these Fogs according to M. Defrance.

(761.) M. Defrance, in a Paper in the *Annales de Chimie*, tom xxxiii., has endeavoured to account for the origin of these Fogs. On some days of Winter, he says, the smoke of village chimneys instead of being elevated in the air, and dissipated in the usual manner, is thrown back again on the ground, and moves over its surface. When this takes place, a current of air has been observed to descend through chimneys which have no fire, producing in the apartments a strong odour of soot, proving the action of descending currents in the atmosphere.* If, therefore, we suppose one or two hundred thousand chimneys to discharge their smoke into the air, and to become mingled with the aqueous vapour, and by the action of currents forced again to descend, a dense Fog like those already described, ought necessarily to happen.

Quantity of moisture deposited by Fogs of this kind.

(762.) The quantity of moisture sometimes deposited by Fogs of this kind, is very remarkable, particularly as no motion is perceptible in them. Dr. Thomson recorded one in 1814, which continued a week, covering London and the country for miles around. It appeared *without visible motion*, and deposited moisture in the greatest abundance. The low temperature, 27°, occasioned, however, some crystalline depositions on the trees, and which were remarked by an ingenious observer, to be *four times thicker on one side than on the other*. Such an excess implied motion, and Thomson inferred from it that six atmospheres must have passed over a given surface in a single day, at the rate of a mile in four hours, and forty-two atmospheres during the whole continuance of the Mist. Copious Mists accompany the setting in of long frosts.

Mists accompany long frosts.

Colours of Mists in this Country.

(763.) Mists have also peculiar colours in this Country. Howard has seen some of a perfect rose colour in the Western horizon, in March and June. One in January also, chiefly of an indigo-blue, but passing below into opake-white, and above into a faint transparent red. Another in May of a transparent brownish-red colour, which gave a pink tinge to the twilight. Daniell mentions also the case of a Mist in London, in August, through which the Sun appeared of a pale blue colour, resembling the flame of Sulphur. The same was observed in Essex and Worcestershire, and Howard saw it in Sussex from nine till near noon, and describes it as of the colour of watch-spring steel.

Mists at Malta.

(764.) When Mists prevail in the neighbourhood of Malta, a particular tinge in the Mist is instantly recognised by the mariners of those seas, as an index of the Island.

Hansteen's idea of cause of Mists.

(765.) Professor Hansteen attributes the formation of Mists to the Polar Lights. The electrical meteors penetrate, he thinks, the vapour of the air, depriving it of its heat, and rendering it opake. When the streamers are flowing, he says, the sky has a tendency to become opake and misty.

Splendid Mist at Cape of Good Hope.

(766.) The great bank of the Lagullas near the Cape of Good Hope has been minutely described by the learned accuracy of Rennel; but Dr. John Davy was the first to trace its effect in promoting that curious condensation of Mist on the Table Mountain, called in the language of the Mariner, "The Table Cloth." On the borders of the bank, the current is strongest, the temperature of the water being at least ten degrees above the neighbouring sea. Such a difference, the Doctor remarks, must produce an effect on the superincumbent air. When a South-East wind blows, it mingles with the warmer air over the bank, the resulting vapour being carried forward to the land. Davy saw it once advancing rapidly over the sea, which it entirely concealed, while the air above was perfectly clear. As soon as it reached the land, it spread gradually along the coast, ascending the mountain and enveloping its summit. There undergoing a further condensation, by the cold contact of the mountain, it descends on the opposite side, and overhangs Cape Town. According to the observations of the Rev. William Hennah, from the Harbour of Rio Janeiro a dry silvery Mist may often be seen creeping down the valleys from the higher land. It begins to form at sunset, and the next morning the whole harbour is densely covered with it.

Mists at Rio Jane

Varied example Mist on hills for- ing Harbour of mouth.

(767.) Many beautiful condensations, but upon a less grander scale, are frequently to be met with on the sea-coast of England. The opposite hills which form the Harbour of Plymouth, and between which the Breakwater lies,—shown by the dark line in the figures of plate ix., afford frequent examples of the kind. Denoting the hill on the left hand by A, the projecting cape in the middle with the tower on it by B, and the wooded mount by C, we shall perceive in fig. 1 a considerable condensation on A, which took place July 22, at 5 P. M., but only a slight condensation on B. Half an hour later, fig. 2 exhibited the appearance of A the same, but on B the Mist had deepened, and encroached partly on C. In fig. 3, the observations being at 6 P. M., the Mist had enlarged on A, but completely enveloped B; on C it had shortened, but increased in altitude. In fig. 4, half an hour later, the appearance of A was the same, and B was enveloped, but with a less elevation of Mist. The portion of Mist on C, which appeared in contact with B in fig. 3, though not really so from the actual locality of the hills, was transferred considerably to the right, leaving the beautiful woody promontory quite clear. The next day at 3 P. M., a continued band of Mist appeared from one headland to the other, at a less altitude above the sea, as in fig. 5. The bottom at A, above the water, and at B were admirably defined, but at C it dropped into beautiful festoons. The Mist disappeared in all parts at once, diminishing from the bottom upwards. The well-defined line and the broken form of the festoon were preserved to the last. The wind was South. On the 2d of June, at 8½ A. M., the form of fig. 6 was exhibited, but the upper boundary of the Mist was not uniform like the last. At 4 P. M. the Mist on A had disappeared as in fig. 7, and a dense cloud apparently reposed on the hill, which seemed to join with the Mist over the water, but the whole of B and C were completely lost in Mist. At 6 P. M. the cloud remained over A, but the Mist at C had formed with a perfectly uniform line below, as in fig. 8. Figs. 9 and 10 contain two views only of C. The former exhibits a Mist reposing on the water, with a perfectly uniform boundary above, and concealing only the *lower* half of the mount; and the latter figure discloses that portion to view, leaving the *upper* enveloped in a Mist of the most perfect uniformity above, but dropping into the most beautiful forms below;—this moment falling in graceful festoons between cedars and oaks; and in the

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* A smell as of something burning, arising from this cause, has doubtless been often remarked by the reader in his house. By night it may, perhaps, have cost him some anxiety.

next, rising suddenly above elms and pines, becoming lost at last in the azure above. For two hours and a half this appearance continued, changing its form every instant, and disclosing infinite varieties of light and shade. Now and then also, tinges of red and yellow, and grey, falling on the misty forms, increased in a high degree the beauty of the scene.

(768.) No description more accurate can be given of the calm Fog, than the following from the masterly pen of the late Mr. Crabbe.

> When all you see through densest Fog is seen,
> When you can hear the fishers near at hand
> Distinctly speak, yet see not where they stand;
> Or sometimes them and not their boat discern,
> Or half-conceal'd some figure at the stern;
> Boys who, on shore, to sea the pebble cast,
> Will hear it strike against the viewless mast;
> While the stern boatman growls his fierce disdain,
> At whom he knows not, whom he threats in vain.

ON CLOUDS.

Remarks on the sky.

(769.) The sky is an object of interest under whatever point of view it be contemplated. Spread out on all sides like a splendid canopy, it presents to the eye in every clime some peculiar characteristic, in England seeming of a lower elevation than in France, and in Italy disclosing a purer and more extended scene.

Small masses of air no colour.

Viewed on a great scale is blue.

This colour augments from horizon to upper sky, and from valley to mountain top.

(770.) Contemplated in small masses, air of a perfectly dry character appears destitute of colour, nor does the presence of moisture in a state of vapour, seem in any way to alter its appearance; but on the great scale in which Nature presents it to our view, it puts on the colour of a lively blue, and we become sensible of the existence of vapour, by the increased distinctness with which distant objects are seen, and the consequent enlargement of the boundaries of the whole visible sky. At the same time, also, the intensity of colour augments by almost insensible gradations from the horizon to the upper sky; and, as the testimony of all travellers confirms, a similar augmentation takes place from the valley to the mountain-top, until the whole hemisphere puts on a deepened indigo tone.

Transparent sky rare in a climate like our own.

Causes. Formation of Clouds.

(771.) A sky perfectly transparent, however, is a phenomenon of very rare occurrence in an insular situation like our own. A variety of causes,—unequal temperatures, diversified currents, and different stores of moisture, soon compel the humidity with which the atmosphere is charged, to put on an opaque form; and rolling masses of visible Cloud are seen, exhibiting every diversity of magnitude, shadow, and form, and sometimes lights and varieties of colour more beautiful than it is in the power of language or the pencil to describe. It is then that the Heavens address a language intelligible to Man;—and which is interpreted by the Philosopher, the Poet, the Painter, the Mariner, and the Peasant, with all the varied feelings which belong to their different occupations and desires, and which Superstition herself has not failed to appropriate to some of her dark and mysterious uses.

(772.) An inquiry into the origin and phenomena of Clouds, is, therefore, far from being an unprofitable branch of Meteorological investigation. Unable to examine the actual constitution of the immense masses of vapour which diversify the sky, we are left almost entirely to the dim light of conjecture respecting them. That they are composed of drops or vesicles of some kind, seems admitted on all hands; and while the optical phenomena they present, entirely exclude the idea of these drops being solid, there is every thing in favour of their vesicular structure; that is of their being made up of innumerable small globes filled with damp air, analogous in some way to soap bubbles. Saussure in one of his Alpine journeys saw drops float slowly before him, having greater diameters than peas, and whose coating seemed inconceivably thin; and Derham, by microscopic observation, obtained very strong proofs tending to the same end. But while the existence of vesicles seems to have a high probability in its favour, there are difficulties in the way respecting their density, which merit a more extended examination.

Composed of vesicles of some kind.

Optical phenomena opposed to their being solid drops.

Probability of their being vesicular.

Seen so by Saussure and Derham.

Formation of Clouds results from union of strata of different temperatures.

(773.) Of the cause of the formation of Clouds, there seems no theory more probable than that which refers them to the union of atmospheric strata of different temperatures, unequally charged with moisture, in the same manner as we have endeavoured already to account for rain. At the time, however, in which this union takes place, electricity is evolved, disposing the watery particles to assume a vesicular form. The vesicular atoms, charged with the same kind of electricity, cause a general repulsion among all the vesicles, imparting, probably, to Clouds their peculiar forms, and preventing them from descending in the shape of rain. In what way the Clouds become charged with electricity, it is indeed difficult to say; but as electricity is evolved in the process of evaporation, there seem grounds for supposing that they are at all times more or less charged with it. Pouillet,* indeed, has endeavoured lately to overturn the theory of Volta respecting the evolution of electricity by evaporation, by showing that nothing of the kind can be traced, unless some chemical combination takes place; but the experiments of the French Philosopher clearly prove that electricity is evolved during combustion; and that the carbonic acid emitted by vegetables is charged with negative electricity, and the oxygen with positive electricity, thereby amply accounting for the vast quantities of electricity so often accumulated in the Clouds.

Vesicular atoms charged with same kind of electricity causes repulsion among particles.

Experiments of Pouillet.

Suspension of Clouds.

Density of vesicles, equal, less, and greater than air.

(774.) If the density of a Cloud were at all times on an equality with the surrounding medium, or less than it, there would be no difficulty in accounting for its suspension. The case of a stationary mass of Cloud, a phenomenon of frequent occurrence, is one that can be completely reconciled to the laws of Hydrostatics; and if the aerial matter with which the vesicles are filled, were saturated with moisture, while the medium they float in is dry, a reason becomes evident why they should be lighter than the air. In such a case, Clouds should rapidly ascend and diminish in size, by their gradual conversion into vapour, and at length vanish entirely away, independently of every consideration of distance, all of which often occur. But if we refer to the condition of vesicles whose density is greater than the air, a phenomenon which in some circumstances of the atmosphere takes place, considerable difficulties present themselves upon the very threshold of the inquiry; and accordingly many ingenious hypotheses have been contrived to account for it. Gay Lussac has had recourse to the action of warm currents, which he considers to ascend incessantly from the Earth during

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* *Annales de Chimie et de Phys.* vol. xxxv. p. 401.

Theory of Gay Lussac.

Theory of Fresnel.

the day.* If the thinnest soap-bubble, says he, be blown in a room, it will never rise, but descend by its own weight; but if formed in the open air, above a heated soil, the rising current pushes the bubble before it, until weakened by its dilatation, or by its mingling with cooler air, the force of its impulsion is found to be in equilibrium with the air; and hence the illustrious Chemist thinks, that the aqueous vesicles may remain suspended at a considerable height, variable according to the Seasons, and greater in Summer than in Winter. To account for the same phenomenon, Fresnel imagines Clouds to be formed of minute globules of water, or very fine crystals of snow, from the extreme division of which, a very multiplied contact with the air is produced. These watery atoms, he further supposes to gain an increase of temperature from the solar and terrestrial rays, and that the air within the Cloud, and in the neighbourhood of its surface, becomes more dilated than the surrounding atmosphere, and consequently lighter. From this hypothesis it results, that the particles composing a Cloud, may be so near each other, as to leave but small intervals between them, and that the particles themselves may be even smaller than those intervals. Hence it follows, that the whole weight of water in a Cloud, forms but a small fraction of the weight of air it contains; and so minute may be this fraction, that the difference between the density of the air in the Cloud, and the air which surrounds it, shall more than compensate it. When the weight of air and water in a Cloud is less than that of an equal bulk of the surrounding air, the Cloud will ascend until it reaches a region where these two weights are in equilibrium. This height will depend on the fineness of the particles of the Cloud, and the intervals which separate them. During the night, the Clouds are of course deprived of the solar rays, and their temperature should become less, but they must still receive warm rays from the Earth; and should their thickness be very great, their temperature will but slowly diminish. Hence a cause is in activity for maintaining the suspension of Clouds by night.

Clouds often in equilibrium with the air in which they are situated.

That masses of Cloud are often in perfect equilibrium with the stratum of air in which they are situated, may be gathered from the fact, that when the mercurial column rises, the Clouds also ascend, to reach a new region which may be in equilibrium with them. The masses of smoke encircling the crater of Mount Etna, ascend and descend with the quicksilver of the barometer; and the motion of the smoke even predicts to the Philosophic Observer, the kind of change going on in the mercurial column.

Great di versities among Clouds.

(775.) A very slight attention to the appearances of the sky will prove great diversities of character to exist among the Clouds which cover it; that there are some Clouds peculiar to one region and some to another; and that among them there are varieties of density and varieties of form; and that some system of classification was called for "to enable the Meteorologist," as Howard expresses it, "to apply the key of analysis to the experience of others, as well as to record his own with brevity and precision." This is what that distinguished Meteorologist accomplished in his admirable nomenclature of the various modifications of Cloud.

Howard' classifica tion of them.

Clouds were divided by Howard into seven modifications, three of which he regards as primary, two as intermediate, and two as compound. They are as follows:

Primary Modifications.

Cirrus.

1. CIRRUS. *Def. Nubes cirrata, tenuissima, quæ undique crescat.* Plate x. fig. *a.*
   Parallel, flexuous, or diverging fibres, extensible in any or in all directions.

Cumulus

2. CUMULUS. *Def. Nubes cumulata, densa, sursum crescens.* Plate x. fig. *b.*
   Convex or conical heaps, increasing upward from a horizontal base.

Stratus.

3. STRATUS. *Def. Nubes strata, aquæ modo expansa, deorsum crescens.*
   A widely extended, continuous, horizontal sheet, increasing from below. Plate x. fig. *c.*

Intermediate Modifications.

Cirro Cumulu

1. CIRRO CUMULUS. *Def. Nubeculæ densiores subrotundæ et quasi in agmine appositæ.*
   Small, well-defined, roundish masses, in close horizontal arrangement. Plate x. fig. *d.*

Cirro Stratus.

2. CIRRO STRATUS. *Def. Nubes extenuata subconcava vel undulata. Nubeculæ hujus modi appositæ.*
   Horizontal or slightly inclined masses, attenuated towards a part or the whole of their circumference, bent downward, or undulated, separate, or in groups, consisting of small Clouds having these characters. Plate x. fig. *e.*

Compound Modifications.

Cumulo Stratus.

1. CUMULO STRATUS. *Def. Nubes densa, basim planam undique supercrescens, vel cujus moles longinqua videtur partim plana partim cumulata.*
   The Cirro stratus blended with the Cumulus, and either appearing intermixed with the heaps of the latter, or superadding a wide spread structure to its base. Plate x. fig. *f.*

Nimbus.

2. CUMULO CIRRO STRATUS *vel* NIMBUS. *Def. Nubes vel nubium congeries pluviam effundens.*
   The Rain Cloud. A Cloud, or system of Clouds, from which rain is falling. It is a horizontal sheet, above which the Cirrus spreads, while the Cumulus enters it laterally and from beneath. Plate x. fig. *g.*

These are the original definitions and figures given by Howard in his celebrated Essay read before the Askesian Society in 1802-3, and are here introduced as standards of reference.

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* A beautiful example of the action of the currents here referred to is to be found in the case of the spiders that produce gossamer. "Apparently actuated by the same impulse," observes Mr. Blackwall, in a most interesting Paper in the XVth volume of the *Linnæan Transactions*, "all the spiders were intent upon traversing the regions of the air. Accordingly, after gaining the summits of various objects, as blades of grass, stubble, rails, gates, &c. by the slow and laborious process of climbing, they raised themselves still higher by straightening their limbs, and elevating the abdomen, by bringing it from the usual horizontal position into one almost perpendicular, they emitted from their spinning apparatus a small quantity of the glutinous secretion with which they construct their webs. This viscous substance being drawn out by the ascending current of rarefied air into fine lines several feet in length, was *carried upward, until the spiders feeling themselves acted upon with sufficient force in that direction, quitted their hold of the objects on which they stood, and commenced their journey by mounting aloft.*"

In what manner Howard limits the term modification.

(776.) The term "Modification" is limited by Howard to the structure or manner of aggregation of a given mass of Cloud, and not its precise form or magnitude, which in most Clouds varies every instant. To the young Meteorologist, it may be at first difficult to distinguish one modification from another, or to trace the narrow limits which sometimes separate the different modifications; but a moderate acquaintance with the subject, will soon enable him to distinguish the varieties as readily, to adopt the language of Howard, "as a tree from a hill, or the latter from a lake; although Clouds in the same modification considered with respect to each other, have only the common resemblance which exists among trees, hills, or lakes, taken generally"

The Cirrus exhibits an unbounded variety.

(777.) The Clouds belonging to the first primary modification exhibit an unbounded variety, and in some conditions of the atmosphere may be observed to undergo perpetual changes. The Cirrus is always to be found in the loftiest regions of the sky, from the smallness of its density, and is the first to be met with in serene weather. Its earliest traces are indicated by fine whitish threads delicately pencilled on a clear blue sky, and as they are augmented in length, others are frequently added laterally. The first-formed threads often serve as stems to support numerous branches, which in their turn give rise to others, sometimes propagated either in one or more directions laterally, or obliquely upward or downward, the same direction often prevailing in a great number of Clouds visible at the same time. Transverse lines are often formed, which, intersecting those in an opposite direction, give to the sky the appearance of delicate network. When the weather is dry, the Cirrus exhibits a more fibrous texture than when it is damp; and whatever may be its figure, its extremities are always fine evanescent points. When the air is damp, it is seen in the intervals of rain, badly defined, and of a less fibrous structure. Cirri of this kind are generally of short duration, and have a great tendency to change into the other modifications. There is often a haziness in the atmosphere when they appear, and they are frequently soon followed by rain.

Earliest traces.

Different examples

Great elevation.

(778.) The great elevation of these Clouds, when formed in their ordinary state, has been ascertained both by trigonometrical observations, and by viewing them from the summits of the highest mountains, where they appear as when seen from the plain. Howard infers their great elevation by noting the time during which they continue to reflect the different coloured rays after sunset, and which they do much longer than any others.

Its continuance very uncertain.

(779.) The continuance of this modification is very uncertain, varying from a few minutes to many hours. The same configuration of Cirrus has been observed in the same quarter of the sky, even for two successive days, during which a smart breeze from the opposite quarter prevailed below. When in the vicinity of other Clouds, their duration is the shortest. Although in appearance almost stationary, they are intimately connected with the variable motions of the air. In fair weather, with light variable breezes, the sky is seldom quite clear of small groups of the oblique Cirrus. These frequently come on from the leeward, the direction of their increase being to windward. Continued wet weather is attended with horizontal sheets of this Cloud, which subside quickly, passing into the Cirro Stratus. Before storms they appear at lower elevations, with a denser character, and generally in the quarter opposite to that from which the storm arises. Steady high winds also are preceded and attended by streaks running quite across the sky in the direction they blow in. Howard observed a Cirrus consisting of many light tufts of a sort of horseshoe figure, rising one above the other. The Cirrus gives every appearance of being a conductor of the electric fluid. Its texture seems to indicate this office, the long parallel and elevated lines which distinguish it being probably employed in equalizing the electricity of remote masses of air. The buoyancy of the Cirrus seems most perfect during its first increase. Many diversified examples of Cirri may be seen in plates xi. and xii.

When in vicinity of other Clouds its duration shortest. Other remarks on the modification.

Dense structure of Cumulus.

(780.) Clouds of the second primary modification are commonly of a very dense structure, and hence are found in the lower regions of the sky, moving gently along with the current next the Earth. Their silent and gradual formation discloses many interesting phenomena. A small but irregular cloud first appears, which sometimes changes into a nearly hemispherical mass, and sometimes rises into mountains of stupendous magnitude and beauty, disclosing summits tipped with the brightest silver. During these transitions, the lower surface of the Cloud continues irregularly plane; and whether the cloudy masses are few or many, their bases always lie nearly in one horizontal plane. Their increase appears to bear at all times a relation to the extent of their bases, and has an evident reference to their mechanical stability. The growth of a Cumulus is a most interesting phenomenon. The shaded mass of Cloud in fig. 3, plate viii. represents a finely formed Cumulus as it appeared at ten A. M. on a calm and brilliant day in July; and the differently dotted outlines surrounding it, show the successive changes of figure it underwent, during six consecutive intervals of five minutes each.*

Characteristics of the Cloud.

Its formation during the day.

(781.) In fair weather, the Cumulus is generally first seen to form some hours after sunrise, to go on augmenting to the hottest part of the day, from which point it declines, and totally disperses about sunset. But while the ordinary variations of temperature in fine and tranquil weather, seem to impress on this modification of Cloud a system of analogous changes, the more variable conditions of the atmosphere impart all their own unsteady influence to them. In such cases they sometimes disappear almost as soon as formed, while in others, they are no sooner formed, than they pass into one of the modifications of a compound kind.

The Cumulus peculiar to fair weather.

(782.) The Cumulus peculiar to fair weather has a moderate elevation and extent, and a rounded surface of a well-defined kind. Before rain it augments with great rapidity, and sinks to a lower elevation, becoming fleecy and irregular in its appearance, and with its surface full of protuberances.

Cumuli during a strong wind.

(783.) The formation of large Cumuli to leeward during a strong wind, indicates the approach of a calm with rain. When they do not disappear about sunset, but continue to rise, thunder may be expected during the night. Forster remarks, that when a Cumulus,

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* And now the mists from Earth are Clouds in Heaven;
Clouds slowly castellating in a calm
Sublimer than a storm; while brighter breathes
O'er the whole firmament the breadth of blue,
Because of that excessive purity
Of all those hanging snow-white palaces,
A gentle contrast, but with power divine.
WILSON.

moving with the wind, has from any cause altered to the Cumulo Stratus, the change has been uniformly attended with a retardation of the motion of the Cloud.

Cumulus performs an important part in the economy of Nature.

(784.) The Cumulus appears to perform an important part in the economy of Nature. While it screens the Earth from the direct rays of the Sun, it diffuses the solar light by its multiplied reflections, and conveys, moreover, immense stores of vapour from the place of its origin, to a region in which humidity may be wanted. Several examples of this Cloud are given in plates xi. and xii.

The Stratus properly the Cloud of night.

(785.) The Stratus, or third primary modification, has its inferior surface resting commonly on the Earth or water. It is properly the Cloud of night, and makes its first appearance about sunset. It comprehends all those creeping mists, which on tranquil evenings ascend in spreading sheets, like inundations of water, from the bottoms of valleys and the surfaces of lakes and rivers. It continues frequently through the night; but on the return of the Sun, its beautiful level surface puts on the appearance of a Cumulus, the whole mass rising at the same time from the ground. The continuity of the Cloud is at length broken, and it ascends and passes away with the appearance of the nascent Cumulus. The Stratus has long been regarded as the harbinger of fine weather. There are few days in the year more calm and serene than those whose morning breaks out through a Stratus. In the New World the most magnificent examples of the Stratus occur. Humboldt mentions one which filled the Valley of Caraccas. It appeared to be full of water, and seemed to be an arm of the sea, of which the adjacent mountains formed the steep shore.

An example of a Stratus is given in plate xi. with a nascent Cumulus above it.

Formation of the Cirro Cumulus. Its beautiful changes.

(786.) In passing to the consideration of the intermediate modifications, the formation of the Cirro Cumulus will be found to disclose the most beautiful system of changes. The Cirrus having remained for some time stationary in its proper region of the upper sky, increases at length in size, which is followed by its descent into a lower region of the air, where it puts on a new character, from the collapsing of its fibres, and its passage into small roundish masses, in which its original texture can no longer be traced. This change of condition takes place, either throughout its whole mass at once, or progressively from one extremity of the cloudy mass to the other; and the same effects may be traced with great uniformity in a number of adjacent Cirri at the same time, and in the same order. In some instances these changes seem to be accelerated by the approach of other Clouds.

Beautiful appearances also when disposed in beds.

(787.) The sky presents a very interesting appearance when several beds of these small connected Clouds are seen floating at different altitudes. These diminish as the eye follows them into the blue expanse. The Cirro Cumulus is frequent in Summer, and is attendant on warm and dry weather. On a fine Summer's evening, the nubeculæ which compose this Cloud are often large, well defined, and detached from each other. The whole sky is sometimes covered with them. This Cloud is also occasionally, but more rarely, seen in the intervals of showers, and in Winter. It either disappears in the region in which it is formed, or by ascending in the atmosphere, reassumes its original condition of a Cirrus; or conversely, by sinking lower in the sky, puts on the form of the Cirro Stratus. In stormy weather, previous to thunder, a Cirro Cumulus often appears, composed of very dense and compact round bodies in very close arrangement. When accompanied by the Cumulo Stratus, it is a sure indication of a coming storm. Examples of the Cirro Cumulus are given in plates xi. and xii.

The Cirr Stratus.

(788.) The Cirro Stratus appears to result from the subsidence of the fibres of the Cirrus to a horizontal position, at the same time that they make a lateral approach to each other. Its figure is very variable, sometimes consisting of dense longitudinal streaks; and at other times, when seen in the distance, it puts on the appearance of shoals of fish. Sometimes the whole sky is so mottled with this kind of Cloud, as to obtain for it the name of the Mackerel-back Sky, from its great resemblance to the back of that fish. It sometimes assumes an arrangement like discs piled obliquely on each other. Frequently it appears like parallel bars, and at other times with interwoven streaks like the grain of polished wood, the structure of the Cloud inviting attention rather than the form. In other cases this Cloud is spread out into plane horizontal sheets, more or less dense. It is always thickest in the middle, or at one extremity, but diminishes towards the edge. There is a variety of the Cloud which presents the appearance of the Cyma in Architecture.

Variable figure.

Mackerel back sky

Cirro Stratus p cedes wi and rain

(789.) The Cirro Stratus precedes wind and rain, and the approach of foul weather may sometimes be inferred from its greater or less abundance, and the permanent character it puts on. This Cloud is almost constantly to be seen in the intervals of storms. The waved Cirro Stratus indicates heat and thunder. Sometimes the Cirro Stratus and the Cirro Cumulus appear together in the sky; and they are even seen to alternate with each other in the same Cloud. During these transitions, a multitude of beautiful phenomena are presented to the observer, and some opinion of the weather likely to ensue may be formed, from the modification which at last prevails.

Alternat with Ci Cumulu

Cirro S tus exhi optical p nomena

(790.) The Cirro Stratus is the Cloud which commonly exhibits the beautiful phenomena of the solar and lunar halo; and by inferences drawn from a few observations, the parhelion and paraselene also. Hence the reason of the prognostic for rain and tempestuous weather commonly drawn from the halo.

Examples of Cirro Stratus are given in the plates last referred to.

Cumulo Stratus,

(791.) The Cumulo Stratus, the first of the compound modifications, occupies a sort of middle state between the Cumulus and rain, and hence in a variable climate like our own, it is by far the most common Cloud both in changeable and very fine weather. The Cumulus seldom preserves its original character long, when the vapour surrounding it is in any excess. In such a case, it either expands spontaneously as it rises, into a spreading crown, with occasional irregular protuberances which overhang its base in uneven or rugged folds, or it unites with the superior modifications already formed by their descending on it. Sometimes this class of Cloud gains additions by lateral increase, from Cirro Strati floating in the same region, or by the union of loose portions of its own kind; and compounds are formed of different kinds, all of which are comprised in this modification. Banks and ranges of Cloud, therefore, of every description, presenting a flattish surface and bounded by vertical or overhanging cliffs, are to be referred to the Cumulo Stratus. Wherever, amidst the light and shade which diversify the magnificent scenery

a Cloud very co monly

Gains a tions b Cirro S

Magnificent aerial scenery presented by it.

of the sky, there is what the artist terms a recess tint, it may be presumed to result from some combinations peculiar to this modification. Trees and towers, magnificent ruins and glaciers, natural bridges and other diversified scenes, which are sometimes fancied in the Clouds, are in general parts of the same arrangement.[*] Before thunderstorms it seems frequently reddish.

Cumulo Stratus seen in profile.

Beautiful form.

(792.) A Cumulo Stratus, well formed and seen singly in profile, is quite as beautiful an object as the Cumulus. Its form, in general, may be compared to a *Boletus*, or to a fungus having a very thick stem and protuberant gills. Howard has occasionally seen specimens constructed almost as finely as a Corinthian capital, the summit throwing a well-defined shadow upon the parts beneath. The Cumulo Stratus is sometimes of vast vertical dimensions. The finest examples of it occur between the first appearance of the fleecy Cumulus, and the commencement of rain, while the lower atmosphere is comparatively dry, and during the approach of thunderstorms. The appearance of the Cumulo Stratus among ranges of hills presents some interesting phenomena. It appears like a curtain dropping among them and enveloping their summits, the hills reminding us of the massy Egyptian columns which support the flat-roofed Temples of Thebes or Tentyra. The more indistinct appearances of it are chiefly confined to the longer or shorter intervals of showers of rain, snow, or hail. Examples illustrating this variety of Cloud may be seen in the plates last referred to.

It has sometimes vast vertical dimensions.

So long as preceding modifications preserve a separate existence, no rain results.

(793.) Any of the Clouds belonging to the preceding modifications, whether existing in a separate class at some uniform elevation, or in two or more classes of different altitudes, may so increase in magnitude, as completely to obscure the sky; or at times, such an appearance of density may be put on, as to lead the inexperienced observer to apprehend a speedy descent of rain. An attentive observation, however, of their phenomena, has induced Howard to infer, that so long as they preserve a separate existence in one of these states, no rain at any time falls from them.

Atmospheric phenomena before rain takes place. Rain from upper regions of sky.

(794.) Before rain takes place, the external characters of the Clouds undergo a change, and their altered conditions have been found sufficiently remarkable to constitute the intermediate modification of Cumulo Cirro Stratus, *vel* Nimbus. When rain comes from the upper regions of the sky, it is indeed difficult to trace the phenomena that occur. All that we can do before the arrival of denser and lower Clouds, is to observe, that, at a great altitude, a thin light veil, or a hazy turbidness exists. When this has considerably increased, the lower Clouds become diffused, and, uniting at length in all points, form a uniform sheet. Rain then commences, and other Clouds from windward passing under this sheet, become successively lost in it. When the latter cease to arrive, or the higher sheet becomes broken, an abatement or cessation of the rain is the result. There often, however, follows an immediate and great addition to the mass of Cloud; but the actual obscurity is lessened, on account of the readier passage the new arrangement affords to the rays of light. On the cessation of rain, the unbroken Clouds below rise into Cumuli, the superior sheets put on the varied forms of the Cirro Stratus, which sometimes pass into the Cirro Cumulus. If the interval be long before the next shower, some form or other of the Cumulo Stratus appears, and sometimes very soon after the first cessation of the rain.

Formation of Nimbus best observed in stormy weather.

(795.) Forster remarks, that the formation of the Nimbus may be best observed in stormy weather. Cumuli may then be seen rising into mountains and afterwards changing into Cumulo Strati, while long ranges of the Cirro Stratus permeate their summits. After existing for some time in this form, they increase in irregularity and size, and at length become of a dark and dense form, with a Cirrose crown extending from the top, and ragged Cumuli entering from below. In the end the whole resolves itself into rain.

Distant shower in profile discloses the formation of the Nimbus best.

(796.) A distant shower in profile discloses the formation of the Nimbus very distinctly. Should the Cumulus be the only Cloud present at such a time, its upper parts may be observed to become tufted with nascent Cirri. Adjacent Clouds also approach and unite laterally by subsidence, the Cirri increasing, and extending themselves upwards and by the sides. These interesting changes are succeeded by the shower. At other times the Cirro Stratus is first formed above the Cumulus, and their sudden union is followed by the production of Cirri and of rain. In either case the formation of Cirri seems to be proportional to the quantity of rain, giving an external character to the Cloud by which it is readily known at great distances, and which induced Mr. Howard to apply to this intermediate modification the name of *Nimbus*.[*] When one of these is transported rapidly by the wind, very little rain is produced, but frequently some hail or driven snow. In heavy showers, the central sheet being once formed, is, as it were, warped to windward, the Cirri being propagated above and against the lower current, while the Cumuli arriving with the latter, cause it to be augmented. Humboldt saw large drops of rain fall at Cumana, when the sky was quite blue, and without the slightest trace of Cloud.

Uses of the Cumulus and Cumulo Stratus as carriers of moisture.

(797.) Since rain may be produced, and continue to fall from the slightest obscuration of the sky by the Nimbus, while a Cumulus, or Cumulo Stratus, of a very dark and threatening aspect, passes on without discharging any, until some change of state takes place, it would seem as if Nature had destined the latter as reservoirs, in which water is collected from extensive regions of the air, for occasional and local irrigation in dry seasons, and by means of which it is arrested at times in its descent, in wet ones.

Nimbus adorned by the rainbow.

(798.) The Nimbus, although one of the least beautiful of Clouds, is, nevertheless, now and then adorned by the splendid colouring of the rainbow, which can only be seen in perfection, when the dark surface of this modification forms for it an extended back-ground. Examples of Nimbi are given in plate xii.

(799.) Masses of Cloud, however, frequently appear, which seem incapable of being referred to any of the

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[*] It must have been this compound modification which suggested to Shakspeare the following splendid and well-known lines.

> Sometimes, we see a Cloud that's dragonish;
> A vapour, sometimes, like a bear or lion,
> A towered citadel, a pendent rock,
> A forked mountain, a blue promontory
> With trees upon 't that nod unto the world,
> And mock our eyes with air.—
> That which is now a horse, even with a thought
> The rack dislimns, and makes it indistinct
> As water is in water.

[*] *Qualis ubi ad terras abrupto sydere* nimbus
It mare per medium, miseris heu prescia longe
Horrescunt corda agricolis.

Clouds which seem to belong to no modification.

modifications; but these, if they continue long enough visible, generally assume some definite form at last; and hence the difficulty which the young Meteorologist sometimes feels, of fixing the modification to which a Cloud belongs. There are Clouds, indeed, intermediate between the Cirrus and Cirro Stratus, or between the Cirrus and Cirro Cumulus, which seem not to partake of the character of either, and which, therefore, it is not easy to name. Loose, shapeless portions of Cloud moving swiftly in the lower current of the atmosphere are called *Scud*. Sometimes a great mass of Cloud will break up into several distinct modifications. One was seen by Howard which became resolved into Cirro Cumulus, into Cirri spreading out into continuous sheets approaching the Cirro Stratus, while flocks of Cumuli floated along in the wind below. To become acquainted with all these diversities, as well as with the more perfect examples of the distinct modifications, requires much diligent observation. The subject has higher claims on our attention than is commonly admitted, and is, perhaps, destined to attain a high rank in Meteorology. Nor should its cultivation be confined to one locality; it should be extended to many diversities of climate, to mountainous and level Countries, so that a body of facts may be collected to enable us to draw more general conclusions than we are yet able to do.

Uniformity of the Clouds.

Circumstances which contribute to it.

Clouds in upper sky roundish, in middle sky oval, and in lower sky linear.

Clouds on opposite sides of sky. Clouds seem to converge.

Clouds appear to cross each other and to converge. Dark segments. Effects of wind.

(800.) However irregularly the masses of Cloud may seem to be distributed in the air, the observer may nevertheless trace, in some way or other, an approach to uniformity. The general aspect of the sky, the tone and lights and shadows of the Clouds, and the laws of the aerial perspective which govern the whole concave of Heaven, each in their degree tends to uniformity, even when the masses of Cloud seem to be dispersed in the utmost confusion. It may be remarked in the first place, that the Clouds which occupy the upper sky, have forms comparatively round, whilst in the middle regions, they appear of an oval figure, and nearer the horizon approach to a linear form, as attempted to be illustrated in fig. 1, plate xiii. On other occasions, detached masses may be seen similarly disposed on opposite sides of the sky, exhibiting dimensions more contracted as they are nearer the horizon, and becoming more extended as their elevation is augmented. At other times, Clouds of an arch-like form are seen to converge with beautiful uniformity towards opposite points of the horizon, as in figs. 2, 3, and 4; while in other conditions of the atmosphere, the bands are confined to one region only of the sky, as in fig. 5; or sometimes they may be seen more numerous, or better defined in dimensions, density, character, or colour, on one side of the sky than on the other. Sometimes the points of convergence are to be seen above the horizon, and sometimes they are invisible below. At other times one only is to be found above, and the other below; or the two points may not be disposed opposite each other, as in fig. 6. Separate arrangements of Clouds may cross each other, each of the series exhibiting a convergency, as in fig. 7. Sometimes a dark segment occupies a portion of the sky, and Clouds proceed from it as in fig. 8, or at other times as in fig. 9. These arrangements are sometimes rapidly dispersed by the wind, and at others are transported in mass quite across the celestial vault. The same band at A, fig. 10, may occupy a position in the zenith, and at length be found on the opposite side of the sky. Sometimes the whole region of the upper sky is covered with dense Cloud, and a perfectly clear band surrounds the horizon; but often instead of this beautiful parallel space, a clear segment only is seen. These and other interesting arrangements of the kind may be seen in *Nouvel Aperçu sur la Météorologie, par* J. A. Clos, Paris, 1828.

Examples given by Howard,

(801.) Such arrangements are far from being uncommon even in our uncertain and variable sky, but they are most frequent in regions where more uniform currents prevail. Howard has recorded many among the notes to his Tables, of which the following are instances. "The haze," says he, "which had long occupied the higher atmosphere, became arranged in long parallel bars of Cirri, extending North-East and South-West beyond the horizon. Cirro Cumulus passing to Cirro Stratus in bars from North to South nearly crossed the visible hemisphere. Bars of Cirri, pointing North and South, appeared to converge in the horizon. Cirro Stratus, and after it Cirri in elevated bars, stretched North and South. Cirro Strati appeared converging to the rising Moon." Parry frequently witnessed the arch-like and continuous forms of the Clouds in the Polar regions, and Humboldt alludes to the same in his *Personal Narrative.*

by Dr. Cl

(802.) An account of an actual example of the progressive formation and appearances of Clouds exhibiting this uniform arrangement may not be uninteresting. On the 19th of June, 1809, at three A. M., Dr. Clos saw the sky very fine, but soon a light-striped Cloud was formed in the West North-West quarter, a little elevated above the horizon. As the Cloud enlarged, it soon presented the figure of a well-defined arch extending from West to East, through the Northern region of the sky, as in fig. 11. The ascending Sun at length was concealed by the arch, and insensibly the sky became flaky in the West, as in fig. 12, the band becoming longer and deeper, and a gentle West North-West wind continuing to blow. These flaky Clouds progressively gained the Eastern region, until at length the rudiments of another arch was seen passing to the South, enclosing the flaky masses between the two bands as in fig. 13. The flaky Clouds in the West at length dispersed, leaving a small portion only in the East, as in fig. 14, the last formed band becoming at the same time more dense, the wind preserving its direction, but increasing in power. The flaky masses in the East at last dispersed, and there remained at half-past six the two bands only, that on the North being diminished, whilst the other was enlarged, as in fig. 15. About seven, the Northern band disappeared, the Southern forming a whitish and slightly dappled segment as in fig. 16. At half-past eight, the latter vanished, the West North-West and North-West wind blowing with increased force, and the sky continuing clear till noon.

Result from illu sions of t atmosph

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Laws of perspect applicab to it.

(803.) All these phenomena are to be classed, however, among the illusions which the atmosphere so constantly presents. The face of the sky, the aerial landscape which delights us with its lovely forms, its snowy palaces, and its torrents of light, is indeed at best but a deceptive picture, and should be contemplated somewhat in the cautious spirit of Geometry. The first visible impressions of the sky are calculated to deceive, and from our earliest childhood we derive from it lessons, which in our riper manhood we are desirous to unlearn. The celestial vault is too often contemplated as a magnificent *superficies*, spread out in beauty before us, without considering that it possesses in every way all the attributes of space, and that the laws of a rigid perspective are disclosed in all its parts. The Clouds which

Motions of Clouds contribute to the deception.

pass in rapid succession before us, contribute in a remarkable degree to increase the deception. Their apparent movements are essentially different from those which are real, and the figures they present, afford no grounds for discovering their proper dimensions and forms. Masses of vesicular vapour that seem to be traversing the great concave of Heaven in a curve of some order, may be really advancing in a uniform right line. The same Cloud which to one spectator may be glowing with light, to another may be enveloped in shadow. That which appears to be its summit may be only a portion of its anterior edge; while that which seems to be its lower bed, may really be a portion of its posterior border. The young observer must indeed apply, with perseverance and caution, to the masses of Cloud that float in the aerial regions above him, some of the laws by which he has learned to discipline his judgment in contemplating the objects that more immediately surround him.

Apparent changes of a Cloud in its transit across the sky.

(804.) Let us endeavour briefly to trace some of the apparent changes a mass of Cloud undergoes during its transit across the sky. In whatever region we are, though a level country will display the phenomenon most strikingly, if a Cloud appear in the distant horizon, and be brought towards us by the influence of a steady wind, its first appearance, whatever be the absolute dimensions of the Cloud, must be very small. By little and little, however, it will rise in the air; and if we suppose, in order to simplify the subject, that its real dimensions remain constant during the whole time of observation, we shall find, that as its elevation increases, its magnitude will augment, and that this alteration will be accompanied by some modification of form. The progress of the Cloud, also, which at first was very slow, will during these changes be accelerated, seeming to advance through the air in a curve. Arrived, however at a certain point, its magnitude will appear to have attained a maximum; but having passed that point, its dimensions will seem to become progressively less and less, its motion proceeding by slower steps and the Cloud diminishing successively in elevation; until reduced apparently at length to a very small mass, it hides itself in the opposite part of the sky from which it emerged. In this way we may trace the phenomena of many Clouds, some moving through the upper sky, and others at a lower elevation on the right hand and left, their magnitudes, forms, and velocities varying in some way every instant, with their ever-changing distance and altitude.

Analysis of the phenomena.

(805.) If we attempt, however, to analyze these interesting phenomena, we shall find that the mass of Cloud did not proceed from the horizon itself; or in other words, was not in contact with the visible boundary around us. Neither was the actual magnitude of the vesicular mass when near the horizon, less than when over our heads, supposing the absolute dimensions of the Cloud to have remained constant during the time of observation; neither were its movements slower, nor did it really describe a curve of any kind in its progress through the air. To illustrate these phenomena, let H Z O, fig. 17, be a vertical section of the celestial vault, passing through the station of the observer S; and for the sake of simplifying the inquiry, let A G be the actual path of the Cloud passing through the same plane H Z O, the projection of which, A Z G, on the concavity of the sky, will be the apparent path of the Cloud. Suppose now A G to be divided into the equal parts A B, B C, C D, D E, E F, and F G, to denote the equal spaces uniformly passed over in equal times by the Cloud. In the actual translation of the Cloud from A to B, it will seem to pass from A to *b* in the vault of the sky, in some time *t*; and in another equal interval, while moving actually through B C, it will appear to describe *b c*, but with a velocity apparently increased. In like manner, when actually moving from C to D, the Cloud's apparent course will be from *c* to Z, with a velocity still more increased. Having passed however D, or its apparent place in the zenith Z, the converse of all these phenomena will take place, both as regards elevation and velocity, until the Cloud finally reaches G.

When actual path of Cloud is in same vertical plane with observer.

When not in same vertical plane.

(806.) Should the Cloud not move in the same vertical plane with the observer, let A G, fig. 18, be its actual path, parallel to a diameter, H S O, of the horizon. If this Cloud be now supposed to move from A to G, we shall find it augment as before from A to I, and diminish from I to G, but its apparent path, by a well-known property of the sphere, will be a curve; and although the actual motion of the Cloud is constantly parallel to the horizon, it will, nevertheless, be seen more elevated in its middle part, and lower at its extremes, the apparent place of B, D, F being at *b*, I, *f*.

Phenomena of a bank of Cloud.

(807.) A bank of Cloud A B C, fig. 19, in the horizon, by ascending gradually to the upper sky, will become elongated like G H I, and at the zenith be extended to K L M. Having passed, however, that limit, it will apparently become shortened, as N O P; and, supposing all other things to remain the same, become reduced at length to its original dimensions D E F, in the opposite horizon.

Phenomena when resolved into three small Clouds.

(808.) If we next suppose this bank of Cloud to be resolved into three small Clouds A, B, C, fig. 20, just emerging from the distant sky, and impelled by the same uniform breeze, the centre mass will pass over the head of the spectator and be enlarged and elevated during its transit to that point; but after passing the zenith, it will diminish in size and elevation as before described, until it disappears finally at E, opposite the point from which it arose. The other Clouds, A and C, as they mount in the sky, will both be enlarged, and have their apparent places, G and H, removed to a greater apparent distance than before from the central mass; but sinking at length at D and F, will regain their original apparent interval in the horizon.

Visible horizon not boundary of Clouds presented to our view.

Phenomena of two neighbouring horizons.

(809.) We are not to suppose that the visible horizon which surrounds us forms the actual boundary of the cloudy masses presented to our view. A bank of Cloud that may seem absolutely lost in the furthest verge of the sky, may indeed be a part only of an enormous mass, extending very far beyond it; and hence, though masses of Cloud may seem almost to converge to a single point, we are not thence to infer that they absolutely terminate there. To illustrate this, let A B, B A′, fig. 21, represent two neighbouring horizons, each being surrounded with its own canopy of the sky. Let *a a′* denote also a continuous band of Cloud, parallel or not paralled to the two horizons. Each of the observers at O and O′ will hence perceive his own band, *a b* or *b′ a′*, bending to the limits, A B or B A′, of his visible horizon, and seeming to have a common point of union at B, the intermediate portion *b b′* being seen by neither. To an observer between the stations O and O′, the mass *b b′* will however be visible. Hence a solitary Cloud driven in the direction *a a′*, though first seen at A, and reaching its maximum of apparent magnitude in the zenith, and disappearing on the other side of the horizon at B, will, nevertheless, though lost to the spectator at O, again emerge out of the same point B, to the observer at O′, as soon as it has arrived at b′ in its actual course. Here undergoing the same system of apparent changes as it did to the first spectator, it will finally vanish at A′. It is just in this way that a Cloud sometimes appears to furnish other Clouds continually, whereas the supply really comes from another sky.

Another illustration.

(810.) But it may be advantageous to the young Meteorologist to put the subject in another point of view. For this purpose let G Z P Y, fig. 22, be the boundary of the visible horizon, and at some height above it, let there be several parallel rows of Cloud, situated in a plane parallel to that plane. If we limit the inquiry in the first place to the three bands D E F, G O P, H I K, the second being found in the same vertical plane with the observer, will pass through the zenith of observation; and by the same laws of perspective as govern a plane higher than the eye, this middle band will have the appearance of descending, and of being lower at the parts most remote from the eye; and supposing its breadth to be uniform, will, as it recedes from the zenith, diminish more and more in breadth, as it successively recedes through the sky. The bands D E F and H I K, however, being out of the vertical plane of the observer, must assume concave forms, as *d e f*, *h i k*, diminishing likewise in breadth towards G and P, where they will seem to unite with the other band. In like manner by supposing other bands, A B C and L M N, to exist, they will be found to put on the appearances of *a b c* and *l m n;* and hence the whole system of parallel bands, however numerous they may be, will all appear to converge and meet in opposite points of the horizon at G and P. That arrangements of this sort, exhibiting the most perfect uniformity, are sometimes visible in this Country, may be seen by referring to the *Edinburgh Journal of Science*, vol. x. p. 33.

(811.) Let us next imagine another observer to be situated at *p*, and of course with another visible horizon surrounding him. Of the parallel bands of Clouds before adverted to, the portions actually existing over his horizon will be B C, E F, O P, I K, and M N; but the apparent positions of these will be b′ c′, e′ f′, e′ p, i′ k′ and m′ n′, all springing as it were from a common point O, and all widening as they seem to ascend in the sky. How different, therefore, the appearance of the *same* portions of these bands to the two observers! To the spectator at O, they will seem to spring up from *p*, diverging in one direction; while to the other observer at P, they will arise as it were from O, and diverge directly opposite. The phenomenon at P will account for those singular forms of Clouds which seem to spring up from the horizon, resembling a human hand. If the parallel bands be of less extent than the visible horizon, they will still exhibit the same tendency to convergency, but may not meet.

Further illustration of great banks of Cloud.

(812.) To illustrate further the phenomena of the great banks of Cloud before adverted to, let A R B, fig. 23, denote the horizon, and A B a large bank of Cloud extending beyond its limits. Should this bed have one uniform thickness, the laws of perspective will necessarily cause its extremities to appear depressed; so that supposing H O, fig. 24, to be the horizon, and H A B O a portion of the real mass of Cloud whose altitude or thickness is H A or O B, its appearance must be that of the segment H C O, the highest part being at C, and the points A and B appearing to unite in the horizon with H and O.

Upper sk covered with Clou and a clea horizon.

(813.) Sometimes the whole of the upper sky is shrouded with very dense Clouds, the lower sky through the whole range of the horizon, being perfectly clear. This arises from the base of the cloudy mass being of a less extent than the visible horizon. Thus if A B, fig. 25, be the extent of the Cloud, and H O that of the horizon, unless the elevation of the Cloud be very small, the points A and B, though apparently depressed, will not seem to meet the horizon; and intervals, H A and B O, of clear sky will exist all around. Should the horizontal extent of the Cloud be equal or greater than the horizon, its extremities will seem to coincide with it; and the whole celestial concave be covered with Cloud as in fig. 26.

Case of whole sky covered.

One side horizon with Clou the other clear.

(814.) Sometimes one extremity of a Cloud may appear to touch one side of the horizon, while the other side remains clear, fig. 27. In this case the Cloud may appear to coincide at H, fig. 28, but its horizontal extent being insufficient to extend to O, the effect of perspective will cause B to be depressed, but not sufficiently to make it apparently coincide with O, and hence a clear space from B to O will remain.

Variety of last.

(815.) At other times a large bank of Cloud will seem to begin at one verge of the horizon, and continue to some distant point opposite, as A B, fig. 29, when other detached Clouds, C and D, may be seen filling up the remaining interval of sky, the last of which appears to coincide with the opposite point of the horizon, the apparent phenomena being as fig. 30. Clear intervals will be seen between B C and C D.

Phenome of successive beds Cloud.

(816.) In some conditions of the sky, we see masses of Cloud disposed in continuous and nearly uniform beds, retiring successively behind each other, the shaded and lower parts of one bed hiding successively the lighter and upper parts of a more distant, but apparently lower bed. These beautiful appearances may be explained as follows: Let C, C, C, C, fig. 31, be four masses of Cloud at equal or unequal intervals, the lower beds, A B, of each being in shadow, while their upper parts are illuminated by the Sun at S. Now although these different masses of Cloud may be disposed at the same elevation, their apparent places will be by no means the same, each mass appearing successively at a lower elevation, in proportion as it is more distant, as C′, C′, C′, C′. Hence the lower bed of the first may conceal the upper bed of the second, the lower bed of the second, the upper bed of the third, and so on; the whole arrangement putting on the appearance of steps, and producing the most beautiful varieties of light and shade.

(817.) It is in the calmest states of the atmosphere, or when no actual current prevails, that the least regularity exists, the effects of a moderate wind being always to bring the masses of wind that may be floating in the air, into something like order. However great indeed may be the regularity of a cloudy sky, it is difficult not to find some traces of uniformity in it.

Mean alt tude of Clouds n known.

(818.) We are unable in the present condition of our knowledge to offer an accurate estimate of the mean altitude of the Clouds, taken either in their separate modifications, or as one great mass of vesicular vapour surrounding the Globe. Contemplated in the latter point of view, it would seem probable that the mean altitude of the whole vesicular mass, bears some relation to the mean conditions of vapour in the air, both as regards its increase from the Equator to the Poles, and from the surface of the Earth, through the higher regions of the atmosphere; but Clouds exist through a wide range of elevation, from the ground, which many of them actually graze, up to the lofty regions where the long lines of Cirri exist; nor are we sure that the highest we see, are the highest that really exist.

Altitudes of Clouds very deceptive.

(819.) Nothing can be more deceptive than our notions respecting the altitudes of Clouds. Their angular elevations can in no way assist us, since the different modifications sometimes appear inverted in the sky. "I have seen," says Forster, "the Cirrus in tufts moving along rapidly in the wind below Cirro Cumulus, and even Cumulus in a higher region," and we know too little of Meteorology to determine whether the phenomena be apparent or real; although the probability is that it is apparent, as the following illustration will prove. Let A, B, C, fig. 32, plate xiii., denote respectively the absolute positions of the Cirrus, the Cirro Cumulus, and the Cumulus, the Cirrus having really the highest elevation, and the other two Clouds occupying their proper positions below. To the spectator at S, the Cirro Cumulus and Cumulus will appear projected on the sky at B′ and C′; whereas the apparent place of the Cirrus will be at A′, below *apparently* the other two Clouds. Again, "I remarked," continues the same active observer, "a long Cirrus moving rapidly along in a North wind, not lengthways, but abreast. At one end of it, fibres pointed backward to the North, while at the other they pointed to the East. Higher up, light Cumuli passed over from the South; and higher still were flimsy, ill-defined masses of Cirro Cumulative Cirro Stratus in an air comparatively calm; but they were found to be passing over gently from North to West." Anomalies like these frequently occur in the pursuit of Meteorology.

Apparent inversions of modifications.

Inhabitants of plains less able to judge of altitudes of Clouds than those of mountainous regions.

(820.) The inhabitants of level plains are less able to judge of the altitudes of Clouds than those of mountainous regions. In Swisserland, for example, the mountains are often intersected in calm weather by horizontal bands of Clouds, whose inferior borders are so uniformly terminated, as to render the smallest change of altitude immediately perceptible. So constant, indeed, are these conditions of elevation, at times, that they remain for days suspended at nearly the same height. In ascending the sides of mountains, the traveller frequently passes through zones of Clouds,* and rising at length above them, beholds the vapours of which they are composed spread out in gentle undulations below him. Mountains therefore, or points on their surfaces, form a sort of scale, by which at least the elevations of the denser sort of Clouds may be measured; but we know of no example of its application, excepting the limited observations of Mr. Crosthwaite on Skiddaw; the comparatively low elevation of that mountain allowing by far the greater proportion of Clouds to pass above it. These observations, continued for five years, are contained in the following Table:

Use of mountains in determining their altitudes.

TABLE CXLI.

Altitudes of Clouds.	Number of Clouds.	Altitudes of Clouds.	Number of Clouds.
From 0 to 100 yards	10	From 600 to 700 yards	416
100 to 200	42	700 to 800	367
200 to 300	62	800 to 900	410
300 to 400	179	900 to 1000	518
400 to 500	374	1000 to 1050	419
500 to 600	486	Above 1050 yards.	2098

Hence it appears, that the *number* of Clouds *above* 1050 yards, were to the number *below* that elevation, as 2098 to 3283, or as 10 to 16 nearly. The theory of Howard not being known at the time these observations were made, the modifications could not be recorded.

Actual measurements of Riccioli.

(821.) Riccioli in his frequent determinations of the elevations of the Clouds by actual Trigonometry, never found them to reach above 4440 fathoms. Bouguer places among the most elevated Clouds, those which he has seen to pass 300 or 400 fathoms above Chimborazo. The Clouds, however, which sometimes mingle with the smoke of volcanoes in that region, rise, he thinks, 750 or 850 fathoms higher. Humboldt remarks, that the large Clouds which the inhabitants of the plains of South America see above them in the air, are contained in an atmospheric stratum of between 1000 or 2000 metres' elevation. Gay Lussac supposes the principal mass of Clouds to be sustained at a height between 1500 and 2000 metres. Dalton has found Cirri from three to five miles above the Earth; and even from the loftiest of the Andes, there are always to be seen delicately formed Clouds of this modification pencilled on the sky. The Clouds of the mackerel-back sky appeared to Dalton almost as distant from the top of a high mountain, as from the valley beneath. Aeronauts have ascended so high that the large Cumuli formed in the lower sky have appeared like "small silvery specks," but no one has ever approached the lofty regions where the lighter modifications abound. Gay Lussac and Biot found at the height of 4000 feet a horizontal stratum of Clouds, whose upper surface was formed into gentle swells. But all these measures are too vague and undefined to satisfy the present wants of Meteorology. The progress of this department of knowledge may eventually disclose to us, not only the mean altitude of the Clouds, but help us to inquire, whether the different modifications do not vary in elevation with the climate and the season, and have not different elevations over different soils, and whether the sea does not modify in some way the altitudes of the Clouds that pass above it. Leslie has made an ingenious theoretical attempt to determine the mean altitude of the Clouds, by means of a formula founded on certain considerations of the density and hygrometric conditions of the air.

Remarks of Bouguer.

Humboldt.

Gay Lussac and Dalton on altitudes of Clouds.

Aeronauts.

Vague and uncertain measures.

Leslie's theoretical attempt.

Distances of Clouds cannot be determined.

(822.) While these difficulties exist respecting the proper altitudes of the Clouds, our judgments become in

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* The following extract from Evelyn's *Memoirs* will be read with pleasure, although, as another able writer remarks, it should remind the reader of a sublimer picture in Burnet's *Sacred Theory of the Earth*. "Next morning we rod by *Monte Pientio*, or, as vulgarly called, *Monte Mantumiato*, which is of an excessive height, ever and anon peeping above any Clowds with its snowy head, till we had climbed to the inn at *Radicofany*, built by *Ferd$^{d.}$ the greate Duke* for the necessary refreshment of travellers in so inhospitable a place. As we ascended we entered a very thick, solid, and dark body of Clowds, w^{ch} looked like rocks at a little distance, which lasted neare a mile in going up; they were dry misty vapours, hanging undissolved for a vast thicknesse, and obscuring both the sun and earth, so that we seemed to be in the sea rather than in the Cloudes, till, having pierced through it, we came into a most serene heaven, as if we had been above all human conversation, the mountain appearing more like a greate island than joyn'd to any other hills, for we could perceive nothing but a sea of thick Clouds rowling under our feete like huge waves, ever now and then suffering thee top of some other mountains to peepe through, which we could discover many miles off; and betweene some breaches of the Cloudes we could see landskips and villages of the subjacent Country. This was one of the most pleasant, newe, and altogether surprising objects that I had ever behold."

a greater degree perplexed with regard to their distances. The union, indeed, is so intimate between distance and magnitude, that it is necessary one of these elements should be known, before the other can be determined. If a Cloud be presented, and an imaginary right line be drawn from the station of the observer to the surface of the Cloud, no estimate can thence be formed respecting its distance. Clouds are seldom so stationary as to permit the ordinary Trigonometrical methods, by two observers taking angles of elevation at the extremities of a known base, to be applied to them with any thing like success. The apparent position of a Cloud in the celestial concave can in no way assist us in determining its distance from us. To the observer at O, fig. 4, plate viii., the Clouds C and C′ have both the same apparent place P, and consequently no estimate can be formed of the distance of either, if indeed other circumstances permit us to distinguish one Cloud from the other.

Deception as to distance during a shower.

(823.) An example of a deception with regard to distance frequently takes place during a shower,—the rain falling nearer to us than we expected. For suppose the real place of the Cloud to be at *i*, fig. 20, plate xiii., while its apparent place is at I, the observer imagines the shower will descend from I, whereas the real place where it falls will be *i*. It may indeed be inferred generally, that Clouds are almost always much nearer to us than they appear.

Magnitudes of Clouds cannot be determined.

Their absolute dimensions cannot be deduced from their apparent.

(824.) The magnitudes of Clouds are open likewise to equal uncertainty. A single mass of Cloud may consist of only a few atoms of vesicular vapour, or it may extend far beyond the limits of the visible horizon, portions of the same Cloud affording an object of contemplation to the inhabitants of very distant places. There seems no method of deducing in practice the absolute dimensions of Clouds from their apparent dimensions; nor are we able at any time to contemplate more than two of these dimensions, the third being either concealed entirely from our view, or so altered from position, as to prevent us from arriving at any definite conclusions respecting it.

Causes of apparent magnitudes of Clouds varying. Illustration.

(825.) The apparent magnitude of a Cloud may vary either from alteration of distance, a change of its absolute dimensions, or from difference of elevation. Suppose F G, fig. 17, plate xiii., to be a Cloud of some determinate form, whose actual path in the air is G A. To the spectator at S, this Cloud will appear projected on the sky in G*f*; and if we suppose the real magnitude of the Cloud to remain unchanged, during the whole time of observation, at the moment the Cloud occupies the position E F, its place on the celestial vault will be *ef*; and when it arrives at D E, its apparent length on the sky will be Z *e*. While the Cloud therefore has preserved a constant length during its absolute translation from G to D, it will have seemed every instant to have increased in length, in its passage from G to Z, and during the time it occupies the zenith, it will seem greater still. As the Cloud, however, gradually retires from that point, its apparent magnitude will go on diminishing, until it is reduced to its orginal dimensions at A. An apparent change of volume, therefore, is no evidence that any alteration of the absolute dimensions of a Cloud has taken place. The apparent magnitude of a Cloud may, however, sometimes be less in the upper sky, than in a lower region thereof; and the point in the sky where a given Cloud may have the greatest apparent magnitude, will depend on the particular figure of the Cloud.

An apparent change of volume no evidence that an absolute change of dimensions place.

Position Cloud i the sky fluences apparen dimensi

(826.) We are, in like manner, incapable of judging of the real forms of Clouds. There must, indeed, be a great difference between the real and apparent forms of the same Cloud, nor can we by any means deduce one from the other. The forms of Clouds must necessarily be subject to considerable changes from a variety of causes, some of which are absolute and others only apparent. The absolute changes are those which result from a real alteration in the whole mass of Cloud, and the apparent those which arise from altered circumstances of position. The same Cloud, it is manifest, must put on different appearances in different positions; and to different observers at the same instant, it must present diversities of form. Nor do these changes relate to figure only but to colour and all the varieties of light and shade.

Effects alteratio position Cloud, i elevatio

(827.) Supposing no absolute change of form to take place, an alteration of position in a Cloud must at once communicate some diversity of appearance. The same Cloud at 20° of elevation cannot present the same form and the same disposition of light and shade, as when it has attained an elevation of 30°. At the first elevation A, fig. 5, plate viii., may appear to be its loftiest summit; but at the second, B, in a much lower region of the Cloud, may seem to be so. The whole surface visible from A to C in the lower Cloud, becomes changed from B to D in the higher. The entire aspect of the Cloud may from this single circumstance be changed.

Of a cu transpo ing it fr one regi of the s to the o

A current, moreover, by transporting the whole mass of a Cloud from one region of the sky to another, without any absolute change of elevation, must produce some changes in its appearance; and an alteration of wind may bring new surfaces into view.

Change form fr new ac sions of matter, dissolut Alterati of dens Centre gravity stability altered.

(828.) But the absolute form of a Cloud may change every instant, either by new accessions of vapour, or by parts of the Cloud being dissolved. The density will thus be varied, and the position of the centre of gravity become sensibly changed, and its buoyancy altogether altered. Its stability also,—an inquiry which has been hitherto singularly neglected, must during these interesting transitions be every moment altered. Sudden condensations may so far alter the circumstances of a Cloud, as materially to change the conditions of its equilibrium; and cases may occur wherein a stable equilibrium may be converted into one that is unstable, or *vice versâ*, and thus prepare the way for new variations.

A curr may c munica rotary motion. The sa Cloud present ferent a pearan person differen localiti

(829.) The action of a current may also communicate to a Cloud a rotary motion about a vertical axis, and thus by another mode disclose new surfaces to view. To persons situated in different localities, the same Cloud must present very different appearances, not only with regard to its entire form, but also in the arrangement of its parts. Thus, in fig. 6, plate viii., a Cloud may be placed between the observers A and B. To one of them, A, the surface presented may appear illuminated by the Sun, while the other surface, to B, may be entirely in shadow. The general forms of the two surfaces may also be very different; and as the Cloud moves towards one spectator or the other, new phenomena must be continually disclosed.

Decept relativ edges limits Cloud

(830.) Very often, what appears to be the superior limit of a Cloud, is no other than the border which is nearest to the eye; whilst that which we regard as the inferior bed, is really the edge most removed from the observer. Thus in fig. 7, though S be really the summit of the Cloud, to the observer at E, the point A will appear the most elevated; and B, which is only the posterior border of the Cloud, will seem to put on the appearance of its base. The same system of Clouds may hence appear to one observer under very different circumstances from what they do to another.

Greatest horizontal axis of a Cloud in direction of wind.

(831.) A Cloud when transported by a current, will always exert an effort to get its greatest horizontal axis into the direction of the wind; and hence the course of the wind ought to determine the direction of the greatest horizontal dimension of a Cloud. A current may so act as to cause a Cloud to advance or recede in a right line from the eye of the observer, and thus give to it the appearance of being stationary. Thus while seeming to be at rest as a mass, its apparent figure and magnitude may undergo considerable changes merely from alteration of distance.

A Cloud may appear stationary when really in motion.

Apparent permanency of a Cloud often an optical deception.

(832.) The apparent permanency and stationary aspect of a Cloud, is often an optical deception, arising from the solution of moisture on one side of a Cloud, just as rapidly as it is precipitated on the other. This is a phenomenon continually taking place among mountains, or upon hills by the sea-side, the Clouds upon their summits appearing immovable, while a strong wind has been acting upon them all the time. The vapour transported by the wind, is precipitated by the cold contact of the mountain; and when carried beyond the cause of condensation, it again exhales and disappears. Similar causes, Mr. Daniell remarks, may operate on either side of the planes of precipitation, at different altitudes in the atmosphere, the vapour being continually condensed, and as continually redissolved in the act of precipitation, the Cloud remaining all the time stationary and unchanged.

Clouds rolling onward without appearing to pass a particular point.

Example.

(833.) Another effect of an analogous kind is that wherein a long succession of Clouds continues to roll onward from the distant horizon, without appearing to be able to pass beyond a particular point. In the Xth volume of the *Edinburgh Journal of Science*, reference is made to a case of this sort, at Mount Edgecumbe in Devonshire, an illustration of which is given in fig. 12, plate ix. "About noon, on the 11th of May, a Cirro Cumulus, of a very dense and definite character, was perceived to come from the verge of the Western horizon with a moderate velocity, and after passing at a small elevation above the woody summit of the mount, vanished in the pure and cloudless air over the tower on the distant promontory. The moving mass formed a continuous Cloud, accommodating itself to all the changes and inequalities of the land.* Over the sea, however, not a Cloud was to be seen; but on the Eastern side, nearly over the flag-staff, the Cloud was perceived to form again, and with a steady and uniform velocity to roll its volumes at nearly the same elevation above the land, until it was again lost in the furthest verge of the Eastern sky. From the West, therefore, there continued incessantly to come forth large and visible volumes of Cloud, which became dissolved in the air just where the sea began to exercise its influence upon them; and where the water lost its power, just above the flag-staff, the vapour became again condensed; so that over the sea, between the extremities of the Clouds, a pure and cloudless sky prevailed; whilst over the land, on both sides, the moving masses continued their courses for upwards of two hours. It was most interesting to watch the gradual progress of the Cloud on the Western side; how steadily it advanced with the gentle South-West wind; how it maintained its character and form up to a particular point; and how soon it became lost in the brilliant expanse of sky, when the temperature of the sea began to exercise its power. Now and then a denser portion of the moving column would detach itself just before it reached the tower, and, passing on with the breeze, seemed to maintain an ineffectual struggle with the influence of the water below; but gradually losing its dimensions and form, would at last vanish." Fig. 11 is a case of a similar kind, but the Clouds were formed in detached masses on the right-hand hill. In fig. 13, the Clouds appeared, on the contrary, in detached masses over the left-hand hill, and a separate bank was formed on each of the peninsulas on the other side. In fig. 14, the Clouds were of a very dense kind over both hills, and their connection was maintained by a narrow, continuous band of Cloud of a less dense kind over the sea; whilst in fig. 15, the whole cloudy mass exhibited the form of a parallel bed, having a smaller density in the middle than at its extremes. All these observations were made during the day. Fig. 16, however, illustrates an observation made on a beautifully serene evening, at nine on the 25th of July, the Clouds being formed over the sea, whilst the air over the land remained perfectly clear. In some of the former figures of the same plate, Clouds were formed on one side, and mists only on the other, the two seeming perfectly united. A beautiful example of condensation is given in fig. 8, plate viii.*

Other examples.

Mountains sometimes cause the Clouds to disperse.

(834.) While mountains, however, commonly occasion condensation, there are examples in which they seem to cause the Clouds to disperse. Mr. Bakewell records an instance of Clouds driving towards Mont Blanc, which seemed to hide it entirely from view. On his arrival nearer the mountain, the cloudy masses disappeared as rapidly at a given point, as they advanced; and although volumes of Cloud continued to move towards the mountain, it remain brilliantly illuminated the whole day It seemed as though the North wind, striking against the mountain, repelled the Clouds; although a current of warm air from the South might have met that which proceeded from the North, dissipating the Cloudy masses before they could reach the Southern range of mountains in the Vale of Chamouni.

Clouds sometimes formed instantaneously.

(835.) Clouds are sometimes formed instantaneously. Saussure remarked an instance of the sort in one of his Alpine journeys. From the side of a lofty mountain, he observed the atmosphere below to be perfectly clear; but in an instant Clouds became formed of two or three fathoms length. So long as the weather remained fine, these Clouds ascended, diminishing as they rose, and at length dissolving entirely in the air. When rain was indicated, the cloudy volumes were augmented, sometimes in the place of their original formation, and at other times during their ascent in the air; and sometimes whilst the vesicular masses descended over the side of the mountain.

Different distribution of Clouds to spectators at different elevations.

(836.) A spectator in an elevated region, as A, fig. 9, may behold masses of Cloud distributed in the atmosphere with very great diversity at different elevations, and presenting all the characteristics of a beautiful sky.

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* A small portion only of the land is shown in the figure.

* Humboldt remarked in the Cordilleras of the Andes, that the conical mountains, such as Cotopaxi and Tunguralma, are oftener seen more free from Clouds, than those mountains, the tops of which are broken into bristly points, like Antisana and Pichincha; but the Peak of Teneriffe, notwithstanding its pyramidal form, is a great part of the year enveloped in vapour, and is sometimes invisible for several weeks from the road of Santa Cruz.

One Cloud in a valley may conceal many in upper sky, or leave a clear sky above.

To another observer, however, at a lower elevation, as at B, the whole canopy of Heaven may appear entirely shrouded with Cloud, exhibiting no diversity whatever. A single Cloud in the valley may conceal the upper sky from the obsevrer beneath, while the spectator on the mountain may contemplate the mass of Cloud below, with all its gentle undulations, yet dense and compact forms, concealing the valley, but permitting, perhaps, an entirely unclouded azure above. Sir H. Davy records an instance, in one of his interesting Letters, of a Cirro Cumulus appearing in this way, and disclosing silver, grey, and blue tints of the most exquisite beauty, the sky above being entirely clear.

When a lower stratum of Cloud is broken up, another layer becomes visible.

(837.) Sometimes when a lower stratum of Cloud is broken up, another layer becomes visible above it. Thus in fig. 10, the spectator at S may perceive through the opening of the Clouds at A, another mass of Cloud floating above, and of whose existence he had no idea before. Sometimes these openings are very numerous, and the higher Clouds which are disclosed, give to the sky an indistinct character. This takes place not only in the upper sky, but at every elevation. In the lower regions, a fine Cumulus at A, fig. 11, may be concealed from the observer by an indistinct mass of Cloud, B. This latter Cloud may break up entirely and disclose the whole Cumulus to view; or it may be partially revealed by its breaking up into detached masses, and presenting an uncertain character, somewhat like fig. 12.

One Cloud may conceal another in lower regions of sky.

Motions of Clouds make known existence of very different currents.

(838.) The motions of Clouds make known the existence of differently directed currents, at different altitudes in the atmosphere. A stream of air may bring a Cloud from the North, and in its course it may meet with a new current, which will transport it to the East. In some other region it may be impelled in a new direction different from the preceding. Sometimes different Clouds may be seen travelling in very different paths through the air, and giving a very interesting aspect to the sky, as in fig. 13, the arrows denoting the directions in which the Clouds proceed. The ascent and descent of Clouds in the air, prove also the existence of vertically ascending and vertically descending currents. Clouds move horizontally also, far beyond the limits of the visible horizon; and likewise in directions having various degrees of obliquity. An inclined current may bring a Cloud into contact with the ground, while another may transport it into a loftier region of the air. Deluc saw a very elevated Cloud descend with rapidity to the Earth and discharge a violent shower of rain; after which, with equal velocity, it remounted to its original elevation. The cause may, however, have been Electricity. In ascending or descending in consequence of altered circumstances of density, different currents may give to a Cloud very different bearings in the sky.

Rapid descent of a Cloud.

Columns of smoke disclose currents.

(839.) Columns of smoke confirm also the same interesting fact; and fig. 14 is an example, observed by Mr. Lauder Dick in July 1817, of the smoke of ignited furze on an eminence several miles distant, which after curling gently upwards, was caught by an under stream of wind and carried seaward in an Eastern and Western direction. After proceeding in this course for several miles, and gradually increasing in elevation, it came at length within the influence of a counter current blowing from West to East, which drove it back at an angle so acute, as to give to the Cloud the appearance of an arrow, and defining very precisely the line *a b* which separated the two currents from each other. The Cloud moving on to *d*, was acted on by a less violent current from the South-East, which transported it to the opposite quarter of the Heavens, where it was eventually lost. A Cloud, it is obvious, might have been acted on in the same way. Small balloons have been employed for making known the existence of currents.

Small b loons al

Inoscul tion of Clouds

(840.) Masses of Cloud of very different characters are often brought into absolute or apparent contact with each other, by the action of currents, or altered circumstances of density in the air. These combinations are sometimes distinguished for their variety and beauty. If we suppose M and N, fig. 1, plate xiv., to be two masses of Cloud, acted on by curents in the directions A and B, a junction at some point or other may probably take place, and a new mass of Cloud be formed at O. The two masses united may then move on in obedience to the stronger current, or an intermediate course be pursued by the necessary composition of forces. A union may result also from masses existing at different elevations, but moving with unequal velocities in parallel directions, A and B, fig. 2, the swifter overtaking the slower, and a junction of the two Clouds taking place at O, exhibiting quite a new appearance to the eye.

produce currents

by alte tions of density

(841.) Altered circumstances of density may likewise produce very beautiful examples of inosculation. A Cumulus with a Cirro Stratus may be situated as in fig. 3, and a change of density may either cause the Cumulus to ascend in a mass and join the Cloud above it; or the Cirro Stratus may descend to a lower level and meet the Cumulus, producing in either case an appearance resembling fig. 4. A Cumulus, Cirro Cumulus, and Cirro Stratus may also exist as in fig. 5, and a mass be formed from the same cause, as in fig. 6. Frequently light and delicate Cirri descend upon the summits of Cumuli as in fig. 7, disclosing the most beautiful union of opposite densities and forms. On the other hand, a Stratus may inosculate with the base of a Cumulus and conceal it as in fig. 8. At other times a Cumulus may be seen with its summit cut off as it were by a perfectly horizontal stratum of Clouds, so as to give to it the form of a table mountain, as in fig. 9. Sometimes a Cirro Stratus intermingles with the base of a Cumulus, but this is of rare occurrence, and but imperfectly represented in fig. 10. The inosculations resulting from changes of density are very slowly produced.

Many exampl

Inoscu tions c be app rent a real.

(842.) But these inosculations may be apparent and not absolute. The former may only alter the appearance of the sky; but the latter not only changes the appearance, but some phenomena result, such as rain, hail, or thunder. Apparent inosculations take place when Clouds are brought into nearly a right line with the eye of the observer, but are still separated by some interval from each other. Thus to the spectator at S, fig. 11, the two Clouds M and N may appear in contact with each other, though there is really a great distance between them; but to the spectator at P, no inosculation takes place. Forster mentions that a Cirro Cumulus may sometimes be seen under a spreading sheet of Cirrus of a milky appearance, like a bas-relief, as in fig. 12. This was no doubt an apparent inosculation. A series of Cumuli appeared in like manner on a dark and dense bank of Cloud, somewhat like fig. 13. Fig. 1, plate xv. is an example of two Clouds brought into absolute contact with each other, and in front of them a long band of thin Cloud, seemingly uniting them together, but which was probably an

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apparent inosculation only. Fig. 2 is an example also of apparent inosculation, where Cirri and a thin transparent coat of vapour were decidedly in front of a mackerel-back sky. Fig. 3 is an instance somewhat of the same kind. Figs. 4 and 5 are examples of banks of Cloud in apparent inosculation with other Clouds behind them.

(843.) Clouds sometimes inosculate with smoke. Howard mentions several cases in his Journals. "The smoke of London," he observes, "when passing away in a body swelled up into distinct heaps, each of which inosculated at its summit with a small Cloud. Groups of the Cumulo Stratus, the Cumulus, and Cirro Stratus occupied the South part of the sky attracting the smoke."

(844.) Showers resulting from inosculation are often mentioned by Howard. "A Cumulus," he says, "inosculated with a Cirro Stratus and showers prevailed. A large Cumulus inosculated both with a Cirro Cumulus and a Cirro Stratus, and a Nimbus appeared."

(845.) It is from the inequalities of light and shade which the Clouds display, that we derive all our notions respecting their apparent dimensions in space, and also of their great irregularities of form. Composed probably of vesicles capable of intercepting in some degree the passage of light, the manner in which they are disposed, as different circumstances of temperature and humidity prevail, must necessarily produce masses of very great diversity of form; and as the causes themselves are for ever varying, their figures must be perpetually changing; and hence it is that the most expert artist, when endeavouring to delineate a beautiful Cloud, finds its figure and very character altered in a single instant of time; and while he is seeking only to catch the general attributes of a Cloud, the shadows and brilliant points it displayed are totally changed; what was light is become darkened; and parts that were shrouded in shadow, are now adorned by the rays of a glowing Sun.

(846.) But the shadows which are disclosed amidst this great system of changes, are nevertheless subject to the laws that govern shadows in general. Wherever the Sun and a Cloud may be situated, some portion or other of the vesicular mass must present a shadow. It may be that the whole surface which it turns to the eye is in shade, or a portion of it only, sometimes its upper part and sometimes its lower; but however the shadows may be disposed, there is something to invite attention, something especially which it may be well for the young Meteorologist to dwell on.

(847.) Let us take as a first example, the case of a Cloud whose section, passing through the Sun at S, fig. 6, plate xv., is A B C D. To a spectator at M, the portion of the Cloud A D will be luminous, the points A, B appearing strongly tipped with the solar light. The hollow portion, however, of the Cloud from A to B will appear dark, particularly on the side next A, and so also will the portion from B to C. The light striking on different parts of a cloudy mass, must therefore disclose brilliantly illuminated parts, and parts having different degrees of shadow. Sometimes a Cloud may present one entire mass of shadow, as in fig. 7; and at other times the upper edge may appear illuminated, as in fig. 8. On other occasions the lower edge may be brilliant, as in fig. 9; and sometimes the middle parts of the Cloud may seem only to be in shadow, a margin round their edges being partially luminous, as at fig. 10,* this last phenomenon resulting from the superior density of the middle parts of the Cloud. These phenomena must depend on the comparative elevations of the Sun and Cloud, and on the peculiar figure of the vesicular mass itself.

parts may be in shadow. Sometimes its middle part only.

Progressive changes of shadows in Clouds.

(848.) The progressive changes of shadows in Clouds, in tranquil conditions of the atmosphere, merely from the altered position of the Sun, are most interesting to trace. Early on a fine Summer's morning, we have seen masses of Cloud, as A, A, A, A, A, ... fig. 11, whose lower parts have been gilded by the solar rays B B, B, B, B, B, ... As the Sun has advanced in elevation, these lower parts have become shaded, and other parallel rays C, C, C, C, C, C, ... have illuminated other portions of the Clouds; and when the Sun has reached a higher region of the sky, a third system of parallel rays D, D, D, D, D, D, ... will render new portions of the Cloud brilliant, and produce other alterations of shadow; and thus every moment new arrangements of light and shade are disclosed.

Shadow on the surface of a Cloud.

(849.) Among a boundless variety of examples, we present fig. 12, as affording an interesting case of well-defined shadows on the surface of a Cloud. At A and B, it may be remarked, are dark and well-defined shadows, projected apparently on an even and snow-white surface, by the elevated portions of the Cloud denoted by C and D. At E a remarkably deep indentation of the Cloud was rendered visible by means of a very intense shadow.

Form of a shadow as variable as Cloud itself. Shadows very different to different observers.

(850.) But the form of a shadow is as variable as the figure of a Cloud itself. If we suppose A B C, fig. 13, to be a vertical section of a Cumulus passing through the Sun at S, the shadows of its projecting masses will be instantly changed, if by new aggregations its section should be changed into D B E; or if by the partial dissolution of the Cloud, the first formed section should sink to B F G. The same Cloud also must disclose very different shadows to observers in different localities.

Shadows differ according to different positions of the Sun.

(851.) The shadings of Clouds must differ also according to the different positions of the Sun. The same Cloud in the morning must exhibit very different shadows from what it does in the evening; and both must differ from the phenomena it presents at noon. If a mass of Cloud be in the Northern region of the sky, in this part of the Globe, it will exhibit different appearances from what it would do were it in the South, and presented a similar face towards us. If we suppose a Cumulus, A B, fig. 14, in the North, and another of precisely the same form in the South, the lower parts of both will be in shadow; but to the spectator at S, the phenomena will be very different. In the Northern mass, A B, the illuminated surface will be turned towards the spectator, and a small part only, perhaps, of the darkened part; but of the Southern mass, A′ B′, its shaded side will be presented to the observer, and, perhaps, a small portion only of its enlightened part. Hence it is, that in the middle of the day in a European sky, Cumuli in its Northern regions are so much more brilliantly illuminated than those in the Southern. The former display the most magnificent forms, glowing with light; whilst the latter seem sunk in vapour, and appear dull and dark.

Different appearances of Cumuli in Northern and Southern sky

(852.) The shadows of Clouds in the different zones

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* There are instances where the edges appear with all the brightness and lustre of silver.

Effects of different elevations of Sun in different zones.

must present many diversities arising from the different elevations of the Sun. If S, fig. 15, be its meridian altitude in the warmer climates of the Earth, and S′ that in the Polar Regions; then will the shadow of the projecting mass A reach to C in the latter case, but will descend so low as D in the former. In like manner, the shadow of B for the inferior position of the Sun, will be at E, but for the superior it will be at F. In the Polar Regions, the lower sides of Clouds must be more frequently illuminated than their upper. There the edges of Clouds near the Sun often present "a fiery or burnished appearance;" and as that luminary never rises more than a few degrees above the horizon, they display these brilliant characters for some time. The lights and shadows of tropical Clouds must be necessarily very different from these.

Comparison of Polar and Tropical Clouds.

The whole body of a Cloud projects a shadow into space,

(853.) But it is not only with the shadows of the parts of Clouds which are thrown on the Clouds themselves that we have to do; the whole of a cloudy mass must project a shadow into space, passing with freedom through the air, until it is interrupted in its course by some other Cloud, or is intercepted at last by the ground. In the case of the shadow of one Cloud falling on another, let S be the Sun, fig. 1, plate xvi., and A and B Clouds so situated, that the shadow of one may darken the whole of the upper part of the other, the Cloud at B thus presenting to the spectator the appearance of fig. 2. Or the positions of the Clouds may be such, that the shadow may be thrown on the lower part of B, fig. 3, its upper part being luminous, the whole Cloud appearing as in fig. 4. The shadows of several Clouds may sometimes be thrown on some single Cloud, producing, apparently, many anomalous phenomena. Thus, in fig. 5, the shadows of the Clouds A, B, C may fall on the Cloud L M; and to the spectator at N, who may contemplate the greater Cloud, without any reference to the small ones, sees in it the dark spaces D E, F G, H I, which he cannot account for. The moment, however, he endeavours to connect the positions of these shaded parts with the situations of the lesser Clouds and the Sun, he perceives at once the cause of the anomaly; and thus may many analogous and perplexing appearances be explained.

which may fall on another Cloud.

The shadows of several Clouds may fall on a single Cloud.

Examples.

(854.) Examples are not wanting to illustrate these beautiful phenomena. Howard mentions the case of a Cumulo Stratus with a bright Sun. An obscurity like the Crown of a Nimbus came down upon the Cumulo Stratus, which could be attributed to no other cause than a shadow. He alludes also to the shadows of Cumuli being projected on the haze above them at sunset. Thus let S, fig. 6, be the Sun in the horizon, A the Cumulus, and B the haze. Such a combination, it is manifest, must exhibit a shadow on the haze.

Shadows of Cumuli projected on haze above them at sunset.

Shadows of Clouds in the air.

(855.) But the shadows of Clouds in the air, disclose the most interesting phenomena. A solitary Cloud may sometimes be seen with its shadow distinctly marked in the atmosphere; but often the shadow is not visible, until it becomes considerably foreshortened a greater depth of particles discloses it to view. The cloudy mass M, fig. 7, may throw out a shadow into space. Above the spectator at E, this shadow may present only the depth of A B; but in a more distant part, this apparent depth will be augmented to D C. These shadows, moreover, may be observed to change their positions with the Clouds themselves.

Shadows of several Clouds.

(856.) But the phenomena become much more interesting, when several Clouds are presented to our view. At sunset, says Howard, a group of dense Cirri cast their shadows into the air. When a Cumulus and Cumulo Stratus were changing into Nimbi, the Sun passed behind a group of dense Clouds in the North-West, and darted broad diverging beams of light, separated by distinctly formed shadows, both downwards to the horizon, and upwards in the air. This effect is feebly shown in fig. 8. In fig. 9 we have an instance of diverging shadows proceeding upwards from behind a Cloud, and above which were several delicately formed Cirri. Some of these Cirri were found in the diverging bands of shadow, and some in the enlightened intervals between; the former, it was remarked, being somewhat darker than the latter. Fig. 10 is an example wherein a wide band of shadows was but barely perceptible to the eye. The Cirri, however, which it covered, were sensibly darker than those which extended beyond it; and it was this difference of tone which first gave evidence of the existence of the shadow.

Exampl

Other exampl shadow

Effects interst in Clo

(857.) At times, diverging bars of light and shade, resulting from the solar rays passing through the interstices of Clouds, present phenomena of a very interesting kind, and an example of which may be seen in fig. 11. The beauty and magnificence of aerial scenery is much increased when fine shadows of any of these kinds are delicately disclosed. An example is given in fig. 12.

Shadov converg to a po Twiligl streake shadow produc percept Clouds

(858.) Howard saw a considerable haze slightly reddened by the solar rays. In the midst of the haze appeared several broad bars of shadow, converging into a point of the horizon, and projected apparently by lofty dense Clouds. The twilight, also, according to the same respectable authority, is at times streaked with converging shadows, the origin of which cannot be traced to any visible Clouds intercepting the light.

Diverg shadow West.

(859.) At sunset, broad diverging shadows are frequently observed among the Clouds in the West, and sometimes their effect is exceedingly fine, particularly when they fall on a coloured twilight. After sunset, Howard remarked some beautiful diverging shadows on a pure, diluted, carmine sky. Such shadows, were they long enough to pass the zenith of observation, ought, by principles already explained, to converge again towards some point of the Eastern sky, opposite the Sun's place, the converse phenomena taking place at sunrise.[*] Dr. Smith, in his Optics, mentions an example of the convergence of long whitish beams towards a point diametrically opposite to the Sun, the converging beams not being so bright as those which usually diverge from him, and the sky beyond them appeared very black. Dr. Brewster saw also an example of diverging beams thrown out in great beauty through the interstices of broken masses of Cloud floating in the West. In the East was a dark black Cloud, which seemed necessary as a ground for the converging rays which appeared on it. The converging beams were very much fainter than the diverging, and the point to which they converged was, as near as could be estimated, as far below the horizon as the Sun was above it. About ten minutes after the phenomenon was first seen, the convergent lines *were black* or very dark. This arose from

These dows o someti to conv toward the Ea and su *versâ*. Examp diverg rays ii East a sunset.

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[*] Saussure, in his ascent of Mont Blanc, saw at sunrise from the station he had selected as his observatory, six rays of a fine purple, which parted from the horizon to the West, precisely opposite the Sun. These rays had their centre a little below the horizon, and extended 10° or 12° from it. He seemed to have had no idea of their being shadows of Clouds in the Eastern sky.

the real beams having become very broad, and of irregular intensity, so that the eye took up, as it were, the spaces between the beams more readily than the beams themselves. Mr. Foggo mentions a case which displayed very delicate but distinct rays in the East, and vanished the moment the Cumulus, which veiled the Sun during their appearance, had somewhat altered its position. When the Cloud, however, had nearly reached the zenith, a broad, conical ray darted horizontally from between the eminences of the Cloud, extending to a great distance. Mr. Faraday, likewise, observed a remarkably beautiful example at sunset, on the 19th of August, in the Isle of Wight. Ten or twelve enormous rays of light and shade, says he, were observed towards the North-East, South, and South-East, all radiating apparently in straight lines from a spot, rather South and East, and just upon the horizon. The atmosphere contained a slight haze, which allowed the Sun's beams to pass forward with but little interruption, but yet in sufficient quantity to reflect a considerable portion of light to the eye. Clouds very far to the West, opposed the progress of the light, and immense parallel shadows were consequently cast in nearly horizontal directions along the sky, over the head of the observer. The difference between these shadows and the intervening illuminated parts, could be observed only after they had considerably passed the zenith of the observer, and had become foreshortened in the Eastern sky, where from the greater depth of mass they became visible. An increased haze in the Eastern part might also have rendered the phenomenon more visible, and hence, from what has been before said respecting parallel bands of Clouds, this system of shadows ought necessarily to meet in some spot opposite the Sun. The phenomenon here referred to is illustrated in fig. 13. The obscure cloudy mass from which the rays seemed to spring, must have been a bank of Cloud, which, from what we have before explained, ought to put on the form of a segment. Howard mentions that he found the diverging bars of light and shade sometimes to result from the great quantities of dust constantly floating in the air. He also alludes to an orange-coloured twilight delicately varied with dusky horizontal striæ.

Objects on the Earth may throw shadows into the air. Shadow of twilight visible in Moonlight, and vice versa. Shadows of persons falling on a Cloud.

(860.) Objects on the Earth may occasion shadows in the air. Thus, (fig. 14,) let A be the observer, S the rising or setting Sun, and M a hill. Such a mass in such a situation with regard to the solar orb, must necessarily project a shadow into the air. Howard records an example of the shadow of the twilight being distinctly perceptible in the moonlight at nine P. M.; but twenty minutes later, the Moon cast an equally strong shadow into the twilight.

(861.) Howard and some friends saw their own shadows, and the shadow of the cliff on which they stood, projected on a cloudy mass below. About half-past six P. M., he says, we perceived a body of mist appearing like a mixture of Cumulus and Cirro Stratus come under the sandy cliff on which we stood, and covering the sea below. The Sun shone clearly in the West, which projected our own shadows, and that of the cliff's edge, upon the Cloud beneath. This is illustrated in fig. 15, where A, B, C are the persons on the cliff, whose shadows were projected to D, E, F, the Sun being at S, the shadow of the cliff itself being G H.

Shadows of Clouds on the ground.

(862.) With the shadows of Clouds on the ground, which sometimes add so much to the beauty of the landscape, we are all familiar. One of their practical uses, is that of finding the altitudes of the Clouds which project them.

Coloured shadows.

(863.) Shadows are said to be sometimes coloured. Leslie remarks that near sunsetting, the shadow of a pencil along a blank card appears a bright azure on a lilac ground. Brougham alludes to some that are purple, blue, and red. Rumford, however, regarded them as mere fallacies.

Effects of shadows on the sky.

(864.) Shadows sometimes impart a high degree of repose to the Clouds, while others produce effects entirely the reverse. The lights and shadows of a serene Summer's evening, are very different from those which prevail when the sunbeams are dispersed in every possible direction by innumerable small flickering Clouds. There are days when the whole sky seems full of jarring lights, and there are others when it is softened into mellowness.

Colouring of the Clouds.

Optical phenomena of the sky.

(865.) The subject of Physical Optics was bequeathed to us by the immortal Newton; and in our own days we have seen the most splendid additions made to the rich inheritance. Meteorology, in the modern acceptation of the term, requires that at least some brief allusion should be made to phenomena, which in every region of the Globe impart so much grandeur and beauty to the sky. The difficulty, however, in beginning such an inquiry, is to know where to stop; and the limits of a brief paper will soon teach us, how very much our best efforts must fall short of the conditions which the present state of the Sciences require.

Colouring of the Clouds.

(866.) The harmonious colouring of the Clouds cannot but awaken a lively curiosity. Their most ordinary appearances must arrest the attention of the beholder; and from the deepened and sublime tone of the thunder Cloud, to the soft and tender colouring of the evening sky, how striking and wonderful is the transition! Who can behold the extraordinary magnificence of the Clouds, and the rapid transitions of colour which they sometimes undergo, without wishing to comprehend the cause of so much variety and splendour?

Passage of light through the atmosphere.

(867.) In the passage of light through the atmosphere, it is known to undergo many important changes. A portion of it is absorbed by the air, even in its purest state; and of the horizontal sunbeams transmitted through two hundred miles of that medium, scarcely a two-thousandth part reaches us. A densely formed Cloud must, therefore, of necessity detain a much larger share; and those dark and sombre forms, which sometimes impart so gloomy an aspect to the sky, can only result from the feeble transmission of the solar light. The brilliant whiteness too, which their edges occasionally disclose, must result from a more copious emission of luminous rays; and Leslie, therefore, has properly remarked, that the depths of shade which a Cloud exhibits, may be regarded as comparative measures of the varied thickness of its mass.

Clouds absorb light.

Their brilliant edges.

Leslie's remark on their shades.

Varied appearances of the Sun and Moon.

(868.) But this absorption of the solar light, brings another and a most interesting class of phenomena into view. While the Clouds have a property of sometimes absorbing equally all the solar rays, as is manifest by the Sun and the Moon appearing through them perfectly white, there are other occasions when they appear in a very different way. In the whole of Italy and the South of France, for example, the Sun lately appeared a pale blue, and instances have not been wanting in our own Country of the same kind. On the evening in which this page was written, its upper limb displayed a deepened orange, and its lower a brilliant red; and every one who has watched the changes of the morning and evening sky, cannot but have noticed the most remarkable varieties of colour. It is to the air, therefore, and to the Clouds suspended in it, that we must look for the cause.

Effects of Clouds.

Their powers of absorption and reflection.

(869.) The different modifications of Clouds, partaking as they do of all imaginable degrees of density and position, and presenting so many different dimensions to act on the Sun's light, cannot but occasion the greatest diversity of absorption, as well as of reflection. While some absorb the blue rays, and transmit a rich vermilion, there are others which exhibit successive transitions of yellow, orange, crimson, and purple, even to a dullish grey; and in the unbounded variety which the sky presents, the calm deductions of the Philosopher are apt sometimes to be lost in feelings of admiration, wonder, and delight.*

Example of a section of a Cloud.

Probable developement of colour.

(870.) Let us suppose, in order to render the subject in some degree intelligible to the young Meteorologist, fig. 16 to represent a vertical section of a Cloud of uniform density, divided into successive strata by a system of parallel rays. The first ray, A B, may pass through so small a number of vesicles, as to cause but a feeble absorption of the solar light, and thus permit that portion of the Cloud to appear nearly white. The second and third rays C D, E F, by passing each through a greater mass of vesicles, must render the absorbing process more active, and thus cause colours of some kind to be emitted from D and F; while the lower ray G H may disclose to the spectator another, or the same colour modified in intensity, at I and H. This last ray, from the form we have given to the Cloud, must, it is obvious, be very differently circumstanced from either of the upper rays, A B, C D, or E F, since the portion of it K I between the two projecting masses, will be acted on only by the air, and not by the vesicular atoms composing the Cloud. The supposition need not be limited to uniform circumstances of density even in the same Cloud.

Different Clouds may disclose diversities of colour by alternate absorptions of same ray.

(871.) Not only, however, may colours be developed by the absorption of light in the successive strata of the same Cloud, but different Clouds may disclose diversities of colour, by alternate absorptions of the same ray. Suppose the common ray A F, fig. 17, to pass through three successive Clouds in the same horizontal stratum of the atmosphere. The portion A B during its passage through the first mass of Cloud, will undergo absorption, and disclose some colour at B. From B to C, the ray will be further modified by the air, and at D it will have undergone another change, either by disclosing a new colour, or the former in some degree modified. For a similar reason, a new alteration will take place at F; and thus three different colours, or three varieties of the same colour, will be presented to the spectator at S. These Clouds may be even so situated as to appear like one mass, fig. 18, thus beautifully blending the colours together; an effect which will be readily understood from what has been already said on the apparent positions of the Clouds.

Position Clouds must infl ence the velopem of colour

(872.) The positions of Clouds must, indeed, considerably influence the developement of colour.* In the immediate vicinity of the Sun, the most brilliant colours may be disclosed, and their vividness and intensity diminish, and at last disappear at some distance from it. Parry records a beautiful instance of some white fleecy Clouds, which, at the distance of 15° or 20° from the Sun, reflected from their edges the most soft and tender tints of yellow, bluish green and lake; and as the Clouds advanced, the colours increased gradually in vigour, until they reached a sort of limit, 2° below the solar orb. As the current continued to transport them, the vividness of colour became weakened by almost insensible degrees, until the whole assemblage of tints vanished at an azimuth 10° from the Sun. Mr. Foggo observed, also, an extensive black Cloud which veiled the whole face of the heavens, to within 10° of the Southern horizon. So dense was the cloudy mass, that the Sun's place was completely concealed from his view. A small portion, however, A B, fig. 19, of the Southern edge of the Cloud, was of a dazzling yellow; and as a chain of scud crossed in rapid succession the illuminated part, each became adorned with the prismatic tints, and each in its turn returned to its first sombre hue.

Vertical rangeme of Cloud or altered elevation the Sun must infl ence the phenome of colour.

(873.) The vertical arrangement of Clouds, or altered elevations of the Sun, must also greatly affect the phenomena of colour. If we imagine A, B, C, fig. 20, to be a vertical section of Clouds, having different elevations, but the same azimuth, and rays S *a*, S *b*, S *c*, be transmitted from the Sun at S, through them, some variety of colour will be disclosed by each successive Cloud; but when by the descent of the Sun to S, or a change in the elevation of the Clouds, other rays are made to pass through them, new varieties of colour may be revealed. Scattered masses, like fig. 21,† must produce a very great diversity, according as the rays proceed in the directions *a a*, *a a*, &c., *b b*, *b b*, &c., or any other.

Absorbe power of Clouds shown in those whi pass befo solar disc sunset.

(874.) The great effects of the absorbent power of Clouds, is admirably shown in those vesicular masses which pass before the solar disc, near the time of sunset. A dense, stationary bank of Cloud, fig. 22, of a deep leaden colour was in contact with the horizon, and above it the solar orb suffused with a beautiful blush of red, diminishing in intensity upward. As soon as the Sun came into contact with the upper edge of the Cloud, a small, but exceedingly dark mass was pro-

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* The phenomena of the absorption of light has, however, been too little studied to permit us to speak with entire confidence of the application of its laws to remote masses like the Clouds. We know, indeed, that many coloured, transparent bodies, both solid and fluid, do not absorb the solar rays proportionally; and that it is in consequence of their unequal absorptions, that they appear coloured by transmitted light at all. We also know that in coloured media, some attack the spectrum at one extremity, some at the other, and some at both; and that though the orange and green rays cannot be decomposed by prismatic reflection, they can be so by absorption. When we consider, therefore, how diversified are the general conditions of the Clouds, what variable circumstances govern their densities, how unequal are their magnitudes, and what different positions they occupy in the great hemisphere of the sky, we may look to the theory of absorption, as having at least very high probabilities in its favour.

Brewster remarks, that the light of the Clouds is partly polarized.

* So great is the effect of position, and so remarkable the differences it produces, that it seems difficult sometimes to believe, that the Clouds which in the evening we see drenched with crimson and gold, are the same as we beheld absolutely colourless in the middle of the day.

† An insular situation like our own, with a climate subject to perpetual vicissitudes, must be best adapted for studying the physiognomy of the sky. Here Clouds are no novelty, and it is their absence from the celestial vault which creates surprise. There are regions, however, where the contrary is the case, and where the appearance of a Cloud at some seasons, engages the whole attention of the inhabitants.

Clouds projected on solar disc sometimes rendered darker.

jected on its disc, as fig. 23, no other part of the cloudy bank seeming to alter its appearance in any way. As the Sun descended, other equally dark Clouds came into view; and when its upper limb arrived at length on a level with the superior edge of the Cloud, it was covered with the very dark forms shown in fig. 24, the other parts of the solar face remaining nearly as clear and as freshly coloured as before.* Now these very dark masses were clearly distinct portions of the great bank of Cloud, and existed while the Sun was above it, although blended apparently in a dense mass, when the light passed obliquely through them, as shown in the section, fig. 25; but when the Sun came into the position of fig. 26, some of the rays passed uninterruptedly between them; and the Clouds themselves being of great horizontal extent, absorbed in a very high degree the light that fell on them. In a case of this sort, as well as in the twilight generally, the hard and well-defined outlines of the Clouds are worthy of observation. Twilight, it has often been remarked, while it takes off the edginess of objects *below* the horizon, more sensibly marks the outlines of those *above* it, when they are opposed to the sky; and the principle is remarkably confirmed in the forms of Clouds.†

Hard outlines of Clouds in the twilight.

Clouds projected on solar disc not always rendered darker.

(875.) While the Clouds in the preceding case were, however, rendered so much darker by being projected on the solar disc, cases occur when the contrary is the case. Fig. 27 is an instance where the Sun's face was coloured nearly as before, and during its descent three masses of extended Cloud were brought into apparent contact with it. The parts of these Clouds projected on the disc, became luminous and coloured, but the parts beyond it preserved their original grey appearance.‡

Richest colours presented by the Cirro Stratus.

(876.) Among the different modifications, the most rich and copious colourings are presented by the Cirro Stratus. Shades of purple, crimson, lake, and scarlet are very common; and cases occur wherein they are tinged with violet. Howard saw two bars of this Cloud of a rich crimson, on a ground of almost a golden hue, extending from South-West to North-East, at the altitude of 20°. Cirri and Cirro Cumuli disclose also very different colours at different times, though their situations with regard to the Sun may be very nearly the same. Howard mentions a case of pink-coloured Cirri at sunset; and also others which displayed tints of orange passing through lake and purple, their edges glowing like bright flame. The burnished appearance of the edges of Clouds in the Polar Regions, we have already adverted to. Masses of Cirro Cumuli disposed in beds, on the decline of day, are sometimes very deeply tinged with crimson or vermilion. Howard mentions a case of a Cloud of this sort, coloured with lake passing into violet. A Cumulo Stratus dissipating beneath a veil of Cirrus at the moment of sunset was seen by him of a light silver grey. During the twilight, this same Cloud became successively yellow, orange, red, purple, dull grey, and finally somewhat red. He saw, also, that the sky seen behind a large Cumulo Stratus under the setting Sun, was of a deep brownish lake colour. When the sky above the setting Sun was of a rich yellow colour, a large bed of the same modification exhibited very beautiful deep red tints. Howard, likewise, saw the whole hemisphere overspread with Cirri passing to Cirro Stratus and Cirro Cumulus, and having an arched lowering appearance, the whole being dipt in a great variety of tints. A splendid exhibition was also made by dense Cirro Strati to the South-East and East, which assumed first a deep blood red, passing through crimson and a gradation of lighter reds to orange, and finally to flame colour. The afternoon and night of the next day proved very wet. There seems, indeed, to be some relation between the colours of the Clouds and rain. He speaks, also, of Clouds beautifully coloured, both at sunrise and sunset, with a double gradation of tints, and in which the successive effects of the direct and refracted rays were very distinctly marked. At Mexico, in extremely fine weather, Humboldt has seen large bands of Cloud having all the colours of the rainbow, spread along the vault of the sky, and converging towards the lunar disc. He saw, also, the thick veil of the Clouds rent asunder in shreds near the horizon, and the Sun on a firmament of indigo blue. The broken Clouds became gilded, and fasciculi of divergent rays, reflecting the most brilliant colours, extended even to the midst of the heavens.* Mr. Foggo mentions a chasm in a Cumulo Stratus driven rapidly by the wind, and through which was seen an extensive Cirro Stratus, entirely at rest in a higher region of the sky, beautifully striped with the prismatic colours.

Cirri and Cirro Cumuli disclose very different colours at different times.

Phenomena of Cumulo Stratus.

Cirri passing to Cirro Stratus and Cirro Cumulus.

Double gradation of tints.

Bands of Cloud having all the colours of the rainbow.

Phenomena of chasms in Clouds.

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* How different are these Clouds from those adverted to by Humboldt of a brilliant whiteness, and through which he has distinguished the spots of the Moon so perfectly, as to give the idea of its disc being placed before them.

† The same fact may be noticed when terrestrial objects are thus presented to the sky. Price, in his Work on the Picturesque, remarks, "that many varied groups and elegant masses of trees, which were scarcely noticed in the more general diffusion of light, in the twilight distinctly appear. Then too, the stubborn clump, which before was too plainly seen, makes a still fouler blot on the horizon; while there is a glimmering of light he maintains his post, nor yields till even his blackness is at last confounded in the general blackness of night."

‡ The projection of Clouds on the solar disc, often discloses many interesting phenomena respecting their formation and texture. In the case last referred to, the cloudy bands appeared of uniform density, before they came into apparent contact with the Sun; but as soon as that took place, the parts on the solar disc immediately disclosed a fibrous structure. A remarkable instance of the kind occurred among some very irregular bands of dark Cloud, the intervals of which seemed to be filled up with Cloud of a less dense, but *uniform* texture, the whole seeming to be *stationary*. As soon, however, as the Sun's disc came into contact with the lighter part of the Cloud, it was immediately covered with an irregular and rapidly moving network, as fig. 28, although no perceptible motion was visible in the great mass of the Cloud, proving at once the fibrous texture of the Cloud, and the rapid motion existing among its parts. When it came into contact with the denser bands, this motion was not perceived.

It may, also, be worth while to advert in a Note to the following interesting phenomenon. When the lower limit of the Sun comes into apparent contact with the upper edge of a bank of Cloud, a curved indentation appears in it, the breadth of which is governed by the apparent size of the part of the solar disc on the edge of the Cloud. When the Sun first appears in contact, the indentation is very small, as in fig. 29, but it gradually increases until the horizontal diameter of the Sun reaches the Cloud, as in fig. 30, after which it diminishes as in fig. 31, and when the Sun finally disappears, the edge of the Cloud becomes instantly restored to its former state, as in fig. 32, the separated parts visibly approaching each other, and appearing to meet in the centre of the indentation. This final restoration of the edge of the Cloud, is often an interesting phenomenon. Sometimes colour is perceptible round the indentation, but there is always a more or less brillant emission of rays. In the morning, the lower edge of a Cloud ought to be thus affected. The phenomenon is probably owing to the diffraction of light. A distant hill at sunset may often be observed to be indented in this way.

* This occurred when a shock of an earthquake was felt about nine P. M. The disc of the Sun was enormously enlarged, distorted, and undulated towards the edges. There is some mysterious relation between the aspect and colour of the sky and volcanic action.

Rapid transitions of colour which the Clouds undergo.

(877.) The rapid transitions of colour which the Clouds undergo is worthy of more attention than it has hitherto received. It would seem to depend on something more than change of position, either in the Cloud or the Sun. Forster mentions an instance of some detached Cirro Cumuli being of a fine golden yellow, but in a single minute becoming deep red.* On another occasion he saw the exact counterpart in a Cirro Stratus, by its instantly changing from a beautiful red to a bright golden yellow. What, indeed, can be more interesting, than when by the breaking out of the Sun in gleams, a Cloud which a moment before seemed only an unshapened mass, devoid of all interest and beauty, is suddenly pierced by cataracts of light, and imbued with the most splendid colours, varying every instant in intensity. Numerous examples occur of this beautiful play of colour, which cannot but remind us of the phenomena displayed by the pigeon's neck and the peacock's tail, by opal and pearl.

Clouds assume their brightest colours a few minutes after sunset.

Most perfect examples of harmony occur in finest weather.

Colour of Alps at sunset.

(878.) After the Sun is set, the mild glow of his rays is still diffused over every part, and it has been remarked that the Clouds assume their brightest and most splendid colours a few minutes after it is below the horizon.† It is in the finest weather that the colouring of the sky presents the most perfect examples of harmony, in tempestuous weather it being almost always inharmonious. At the time of a warm sunsetting, the whole hemisphere is influenced by the prevailing colour of the light. The snowy summits of the Alps appear about sunset of a most beautiful violet colour, approaching to light crimson or pink.‡ It is remarkable, also, as an example of that general harmony which prevails in the material World, that the most glowing and magnificent skies occur, when terrestrial objects put on their deepest and most splendid hues.§ It has, also, been observed, that it is not the change of vegetation only which gives to the decaying charms of Autumn their finest and most golden hues, but also the atmosphere and the peculiar lights and shadows which then prevail; and there can be no doubt, on the other hand, that our perception of beauty in the sky is very much influenced by the surrounding scenery. In Autumn all is matured; and the rich hues of the ripened fruits and the changing foliage, are rendered still more lovely by the warm haze which a fine day at that season presents. So, also, the earlier trees of Spring have a transparency and a thousand quivering lights, which in their turn harmonize with the light and flitting Clouds and uncertain shadows which then prevail.

Peculiar lights and shadows of Autumn and Spring.

Splendid displays of colour when no Clouds appear.

(879.) But there are magnificent displays of colour, both in the morning and evening, when no Clouds can be seen. This may, probably, be accounted for on two suppositions, and both in unison with the theory of absorption. The air, uninterrupted by Cloud in its whole horizontal extent, may so absorb particular rays, as to disclose the glowing colours referred to; or there may be actual Clouds existing far beyond the limits of our visible sky, which absorb the light, and produce the same splendid effect. This last supposition will not be objected to, when we refer to the dark lines seen by Fraunhofer in the solar spectrum. Do not these dark lines, it has been asked, occupy the place of rays of particular refrangibilities, which have been absorbed in their passage from the Sun, before they reached our atmosphere? a condition seeming to be necessary from the absence of these lines in the spectra of the fixed stars. Have they not, it has been asked by Herschel, been absorbed in the solar atmosphere? We may apply to this subject, as well as to other parts of Meteorology, the remark of Bacon, "I would not have it given over, but waited upon a little."

Effects of Clouds far beyond the limits of o visible sky Elucidated by dark lines of solar spectrum.

Different examples beautifull coloured skies.

(880.) The following are incidental but valuable examples gleaned from Howard and other respectable authorities. At sunset Howard saw in the West a clear lemon-coloured space, close to the horizon. Above were crimson lights, with shadows of grey and purple in a variety of figures, streaked, waved, and clustered. In the *East* were Clouds, some rose-red, and others of a tender green. He speaks, also, of a ruby-coloured twilight; of orange surmounted by rose-colour; of a sunset with a pure dilute carmine tint; also of a sky on the decline of day reflecting a bronze hue from some Eastern Clouds. About the time of sunset also, or sometimes a little after, the lower part of the sky, to some distance on each side of the place of his setting, may be seen to incline to a faint sea-green. At greater distances this gradually changes into a reddish brown, the colour of the horizontal sky on the opposite side inclining sensibly to purple. In the different voyages to the Polar seas also, are some brief and scattered notices worth collecting. Ross frequently saw a yellow sky. In the South-East and South-West at sunrise and sunset, Parry saw, generally, near the horizon, a rich bluish purple, and a bright arch of deep red above, one mingling imperceptibly with the other. About the time of sunset in these regions, the part of the sky within 1° or 2° of the horizon, was of a bright red, above which was a soft light blue, passing into delicate green. At sunset in December, the sky was beautifully red near the Southern horizon, and a soft rich purple to the North. Saussure remarked in his ascent of Mont Blanc, that the evening vapour which tempered the Sun's brightness, and half concealed the immense space he had below him, formed the finest purple belt encircling all the Western horizon; and as the vapour descended and became more dense, this belt became narrower and of a deeper colour, and at last of a blood red. At the same instant, some Clouds darted a light of such brightness, as to resemble meteors or flaming stars.

In our ow Country.

In the Po lar seas.

In the Al

(881.) But the colour of the sky is often influenced by reflection from terrestrial objects. Ross mentions, that while the Sun and Moon were passing in azimuth along the tops of the mountains, the snow which covered them, and which had naturally a yellow tinge, had then the lustre of gold, the reflection of which on the sky produced a green so delicately rich and beautiful, as to pass description. Other causes, also, sometimes operate. Humboldt remarked when the air was clear and the sky of a very deep blue, that the horizon reflected a livid and yellowish light, which he thought resulted from the quantity of sand suspended in the air

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* No one more than the Meteorologist requires a knowledge of the combinations of colour, so infinitely varied are the tones of Nature, both in the same and different Countries. Who can venture to imitate by the pencil the endless varieties of red, and orange, and yellow, which the setting Sun discloses, and the magical illusions which all the day diversify the vast and varied space the eye travels over in rising gradually from the horizon to the upper sky. Those who have paid any attention to colours must be aware of the difficulty of describing the various tints and shades that appear, and which are known to amount to many thousands. It would be useful if our Meteorologists would endeavour to record in some way the various colourings of the different modifications, and also their elevations at the time of observation.

Example of a sunset from Howard.

(882.) It may be useful to advert to a single example of a sunset, recorded by Howard. The Sun set, surrounded by a moderate glow of flame colour, and without a spot on the Western sky. An extensive brightness remained in the horizon, which insensibly vanished upwards and towards the North-East and South-West. Opposite to this, and quite distinct in its boundaries, appeared a mass of colour resting on an extensive violet or purplish base, in the horizon, and which, diminishing as it rose, terminated at length in a rose-coloured apex. As this apex passed away, an orange tint in the North-West spread and deepened, and was suddenly surmounted by a fine blush of red, completing a grand pyramid of coloured light, reaching half way to the zenith, and glowing every moment with increased brightness; so that half an hour after sunset, the landscape to the East was actually in a much stronger lighter than after the disappearance of that luminary. At the moment this was in the greatest perfection, the opposite pyramid was no longer visible, and the twilight passing off, the red first vanished, the orange spreading upward, at the same time it grew fainter with the white light of the picture.

Cause of morning and evening Clouds displaying a richer colouring than at noon.

(883.) We may gather from what has been advanced on the absorption of light, and from the necessary arrangement of the dimensions of Clouds in the air, a reason why the morning and evening skies display a richer colouring than when the Sun is in its meridian splendour. The stability of Clouds requires that their horizontal dimensions should, in general, be greater than their vertical. In the morning and evening, the former dimension is so situated, as to call into the greatest activity the absorptive power, when taken in conjunction with the great range of horizontal air; whereas in the middle of the day, not only is there a smaller dimension of the Cloud, but a much less quantity of air acts on the light. The increased rarity of the air in Tropical climes, may afford also a reason why the sunsets there are less brilliant than in Countries more remote from the Equator. The continued low elevation of the Sun in the Polar Regions, will likewise explain the more frequent occurrence of rich and splendid skies in that region. Very much remains to be done to perfect our knowledge of the phenomena of Clouds, and we hope it is a subject which will meet with increased attention from Meteorologists.

Tropical and Polar sunsets.

Halos, Parhelia, &c.

(884.) There are other remarkable exhibitions of colour in the atmosphere connected with the Sun and Moon, which have very much occupied the attention of Philosophers. In a clear sky these luminaries exhibit their discs without any change of colour; but in other conditions of the air, they not only undergo alterations of colour, but are also surrounded with circles and parts of circles of various sizes and forms, and exhibiting diversities of the most singular and remarkable kinds.

Formation of corona.

(885.) When a thin stratified Cloud passes before the Sun or Moon, a portion of the Cloud surrounding the luminary appears much more luminous than the rest, as in fig. 1. pl. xvii., the phenomenon being then denominated a Corona. These coronæ depend, probably, on the existence of a number of particles of water, of equal dimensions, and situated in a proper position with respect to the luminary and the eye. There being so much diversity in the magnitudes of the spherules of water, their dimensions may be expected to vary without limit, and by observation they are accordingly found to do so. Coronæ are very common, and are best seen round the Sun by reflection from the surface of still water. Newton saw in this way, three rings of colour surrounding the Sun, like small rainbows, the innermost being blue next the Sun, red without, and white between. The second ring was purple and blue within, pale red without, and green in the middle. The third ring was pale blue within and pale red without. The diameters of the rings were respectively 5° or 6°, 9½°, and 12°.

Very common. Best seen by reflection from still water.

Newton's example.

Halos round the Sun.

(886.) On other occasions circles more or less brilliant, and of a much larger size, surround the disc of the Sun and Moon, the luminary occupying the centre, as in fig. 2. These are denominated halos. Those belonging to the Sun are generally tinted with colours less bright than the rainbow, and sometimes quite as distinct. These colours, however, are variously disposed. Sometimes the red is next the Sun, and a pale blue on the outside; but at other times indigo and violet are without. Frequently they are red or yellow on the inside, and white on the outside. One halo was seen, the middle of which was white, after which followed red, blue, and green, its outermost border being a bright red. In another case a pale red on the outside was followed by yellow and green, terminating with white. The space included within the halo is frequently of a most intense grey, or of a deeper blue than the rest of the sky, when the atmosphere is misty, or of a transparency more or less perfect. Under some circumstances a second halo is formed, much larger than the first and concentric with it, as in fig. 3. Its colours are very pale, and its whole splendour much less than that of the halo within. Frequently, from peculiar conditions of the atmosphere, neither the first nor second halo is perfectly formed, as fig. 4.

Tinted with colour.

Space within halo frequently an intense grey.

Halos sometimes imperfectly formed.

Halos round the Moon.

(887.) Halos round the Moon are formed sometimes of a luminous white circle, and at other times are tinted with pale red alone, or green and red. The white circle is sometimes well defined on the inner side, so as to make the included space appear dark, while on the other side it passes insensibly into the colour of the sky. A succession of these halos frequently occurs. A corona is sometimes formed within the halo, as fig. 5; and Howard observed a case where the corona was not formed by the Clouds which produced the halo, but by haze probably nearer the Earth.

Succession of halos.

Corona within a halo.

Halos seen in a mist.

(888.) Professor Strehlke of Dantzic, in passing over some fields at midnight in August, 1828, was greatly surprised at the successive appearance and disappearance of halos. Some of the fields were covered with mist, and others perfectly clear. In a field free from mist no halo could be perceived; but in those covered with mist, three, or even four halos were perceived at small distances from each other, with very vivid colours, red being always on the outside. Howard saw a lunar halo of moderate diameter, which, disappearing, gave place to a portion of a very large one. In the Polar Regions Parry remarked that halos almost always began to make their appearance about the time of full Moon.

Vary according to climate.

(889.) Coloured circles are, however, much more rare in the Countries of the North, than in Provence, Italy, and Spain. Under the Torrid zone beautiful prismatic colours appear almost every night. Often in the space of a few minutes they disappear several times. Between the 15th degree of latitude and the equator, small halos surround the Planet Venus, orange, purple, and violet being distinctly perceived. Humboldt, however, never saw any colours around Sirius, Canopus, or Achernar.

Marriotte's theory of their formation.

(890.) Marriotte accounted for the formation of halos from the refraction of prismatic crystals of ice descending through the air in all possible directions, and these receiving the solar rays under every variety of inclination. In certain positions of these prisms, it may be proved that light suffers, in transmission through them, a mininum deviation; and this position is determined by the condition that the refracted ray forms with the two sides of the prism an isosceles triangle; or, which comes to the same thing, the angle of refraction is equal to half the refracting angle; and as the refracting angle is here 60°, the angle of refraction must be 30°, and the angle of incidence about 41°. Hence the deviation is equal to double the angle of incidence, *minus* the refracting angle; or $2 \times 41^\circ - 60^\circ = 22^\circ$, and which, singularly enough, coincides nearly with the semidiameter of the solar halo. In other positions of the prism, the deviation increases very slowly, till it becomes a few degrees greater. Hence the breadth of the circles of colour being considerable, the colours must fall principally on each other, and thus become very indistinctly separated. The external circle may be referred to the effect of two such refractions in succession. This mode of explanation could be put at once to a decisive test, could the diameters of halos be measured with the same exactness as the rainbow; but it is seldom the phenomenon is presented with all the uniformity and precision desirable.[*]

Light of halos refracted.

(891.) Arago made an observation which proves in a certain degree, that the light of halos is refracted, having found that it is always polarized by refraction and not by reflection.

Halos may afford us information respecting temperature of higher regions of the air.

(892.) One useful Meteorological inference may be drawn from these Optical inquiries respecting halos, and that is if the presence of icy particles be necessary for their formation, they may be regarded as furnishing us with some data respecting the temperature of the higher regions of the air.

Indications of weather.

(893.) Halos, from their relation to the modification Cirro Stratus, in which they chiefly occur, are found to indicate wind and rain, and sometimes, at the approach of Winter, snow and frost, at which time the colours are very brilliant. Late in the Spring, Howard has repeatedly observed a large white lunar halo to be followed by hot weather.

Appar forms o halos.

(894.) The apparent form of the halo is that of an irregular oval, wider below than above, the Sun being nearer their upper than their lower extremity. This results from the apparent figure of the sky. Parry measured several, and found all the diameters of each to be equal.

Parheli

(895.) Parhelia consist in the simultaneous appearance of many Suns, images of the true Sun. These images always appear at the same elevation as the true Sun, and are always united to each other by a white circle, likewise horizontal, and whose pole is in the zenith. This circle changes its elevation with the true Sun; and its apparent semidiameter is always equal to the distance of this luminary from the zenith.

Cause o whitene the circ

Of colo parhelia

Parheli someti without halos. Cause.

(896.) The whiteness of the circle here alluded to, results from the refraction of the vertical faces of crystals, supposed to be scattered equally through every variety of azimuth; and to the refraction of vertical prisms must be referred the coloured parhelia which impart so great an interest to the sky. These coloured parhelia are not always confined to the limits of halos, but are sometimes formed a little without them, on account of the deviation of the light which passes obliquely through the vertical prisms, being somewhat greater than that of the light transmitted by those crystals which have their axes perpendicular to the planes of incidence and refraction. So also, Dr. Young observes, the light which passes through the horizontal crystals, at different azimuths, is variously modified, so as to produce the beautiful phenomena of inverted arches touching the halos at their highest points; or the many other diversified combinations of arches which at times almost baffle description.

Inverte arches touchin halos.

A simpl parhelic

(897.) The simplest example of a parhelion is that wherein one fictitious Sun only appears on one side or other of the true Sun, on a suitable Cloud,—perhaps vapour passing to a Cirro Stratus Cloud, as in fig. 6, where S is the true Sun, and S¹ its image; or, as in fig. 7, where the fictitious Sun S¹ is below the real Sun S. Both these are actual examples.

Two pa lia.

(898.) The next degree of complexity is when fictitious Suns, S^1, S^2, are formed on each side of the true Sun S, on a proper Cloud, as in fig. 8, the apparent Suns being probably more or less tinted with the prismatic colours, and with or without a luminous circle passing through them.

(899.) Parry records a case of two parhelia, S^1, S^2, as in fig. 9; that to the Westward being formed on a thick, dark Cloud, was bright and prismatic, the other on the blue sky being scarcely perceptible. A ray of bright yellow light extended horizontally about 3° or 4° on each side of the parhelia, and a stripe of prismatic colours from each of them to the horizon.

Rays of low ligl

Three helia.

(900.) Another modification is when three parhelia, S^1, S^2, S^3, appear, with a circle more or less perfect passing through them, as in fig. 10. Parry, who describes one of this kind, remarks that the prismatic tints were much more brilliant in the parhelia than in any other part of the circle, red, yellow, and blue being, however, the only colours that could be traced, red being nearest the true Sun.

Three helia w peculia brightn

(901.) On another occasion, when some snow-drift prevailed, and three fictitious Suns, S^1, S^2, S^3, appeared, with a portion of another circle above, as fig. 11, the parhelia were at times so bright as to render it painful

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[*] The following experiment by Sir David Brewster illustrates in a pleasing manner the actual formation of halos.

"Take a saturated solution of alum, and having spread a few drops of it over a plate of glass, it will rapidly crystallize in small flat octohedrons, scarcely visible to the eye. When this plate is held between the observer and the Sun, or a candle, with the eye very close to the smooth side of the glass plate, there will be seen three beautiful halos of light, at different distances from the luminous body. The *innermost halo*, which is the whitest, is formed by the images refracted by a pair of faces of the octohedral crystals, not much inclined to each other. The *second halo*, which is more coloured, with the blue rays outwards, is formed by a pair of faces more inclined; and the *third halo*, which is very large and highly coloured, is formed by a still more inclined pair of faces.

"Each separate crystal forms three images of the luminous body, placed at points 120° distant from each other, in all the three halos; and as the numerous small crystals have their refracting faces turned in every possible direction, the whole circumference of the halos will be completely filled up.

"The same effects may be obtained with other crystals, and when they have the property of double refraction, each halo will be either doubled, when the double refraction is considerable, or rendered broader, and otherwise modified in point of colour, when the double refraction is small. The effects may be curiously varied, by crystallizing upon the same plate of glass crystals of a decided colour, by which means we should have white and coloured halos succeeding each other."

to the eye to look upon them. A horizontal circle of white light passed through the Sun's disc, and across the parhelia S^1, S^2. A column of light also descended from the Sun, as represented in the figure.

(902.) In a similar case with three parhelia, S^1, S^2, S^3, and a surrounding halo, Parry saw many rays of continuous white light proceeding from the Sun S, and extending in various directions beyond the halo. These rays were brighter after they had passed the halo, than in the part within it. This is shown in fig. 12.

(903.) Mr. White saw at Bedford a beautiful combination of this kind. A B, fig. 13, is the Western horizon, and S a portion of the solar disc, appearing like burnished gold above a dark Cirro Stratus Cloud. S^1, S^2, S^3 are three parhelia, and *d e* a column of white light, reaching to the horizon below, and extending indefinitely upwards; *f*, *g*, *h* were fragments of a solar halo, exhibiting the prismatic colours; *i*, *k*, *l* three luminous trains of lights, terminating in points, the train *k* being highly coloured with yellowish red vapour, owing probably to its being situated in the centre of the column of light *d e*. The train *m* terminated abruptly, but was more distinct than the train *n*, which ended in a point.

(904.) We have before remarked that parhelia S^1, S^2 are sometimes formed outside the halo, but it is rare. Parry remarks, that on one occasion, an officer reported the angular distance between the parhelion and the Sun to be 24° 40′, and the radius of the halo 22° 30′. This was regarded for the time as an error, but subsequent observations abundantly confirmed it. On this occasion an inverted portion of another halo touched the usual halo in a point immediately above the Sun, as in fig. 14.

(905.) Sometimes parhelia S^1, S^2 appear on each side the Sun S, with a halo passing through them, and two inverted arches above, one touching the perfect halo, and the other formed above it. Both the fictitious Suns had tails of a whitish colour proceeding from them, as fig. 15.

(906.) A second halo may surround the first, as in fig. 16, with an inverted arch above it, as well as on the interior halo. This was an example seen by Martin Folkes, P. R. S.

(907.) A still more complex form is, however, sometimes presented, as fig. 17, and which was observed by Parry, where S is the true Sun, having an altitude of about 23° above the horizon *h h*, and *t u* an entire horizontal circle of white light, whose plane passes through the Sun. Immediately below the Sun, at S^1, was a very bright and dazzling parhelion, but not prismatic; and on each side, at the intersections S^2, S^3 of a circle S^1, S^2, *d*, S^3, whose radius was $22\frac{1}{2}°$, with the horizontal circle *t u*, prismatic parhelia were formed. In contact with the upper part of the halo was an arch, *x d v*, of an inverted circle, having its centre apparently about the zenith, and very strongly tinted with the prismatic colours. Above this arch was one, *k e l*, apparently elliptical, the point *e* being distant from the Sun about 26°. The portion included between *x* and *v* was prismatic, but the rest white. The space between the two prismatic arches, *x*, *e*, *v*, *d*, was extremely brilliant by the reflection of the Sun's rays from the innumerable minute spiculæ of snow floating in the atmosphere. Surrounding the whole was a circle, *q f r*, having a radius of 45°, strongly prismatic about the points *f q r*, and faintly so in all its other parts. Above this large circle was a small inverted arch, *m n*, strongly prismatic, and having its centre apparently in the zenith. Springing from the points *q* and *r* were arches, *r p* and *q o*, of large circles, very strongly prismatic. In the outer circle, two spots, *y y*, more strongly prismatic than the rest, were perceptible.

Three parhelia with several halos.

(908.) But three fictitious Suns, S^1, S^2, S^3, are at other times very differently disposed, and producing very different phenomena, as in fig. 18. In this case S is the real Sun, having a very bright halo of the ordinary size surrounding it, tinted with the prismatic colours. On its upper limb, a bright fictitious Sun was formed, as S^1, the rays of which produced a second halo of a smoky white colour, well defined in its whole circumference, and double the diameter of the other halo. S^2 and S^3 were other fictitious Suns, the rays from which formed the circles *m n*, *r p*. The rays thrown off also at the intersection of these circles at *n*, formed segments *q*, *r* of a fifth halo, about 120° of which was below the horizon.

Four parhelia with several halos.

(909.) Four parhelia, S^1, S^2, S^3, S^4, appear sometimes disposed, as in fig. 19. This splendid example was seen by Hevelius at Dantzic, 20th February, 1661. Four parhelia were also observed by Mr. Whiston, as in fig. 20. The true Sun S had a halo surrounding it, and two arches touching the halo and each other at V. At M appeared a smaller arch, convex also to the halo. The parhelia S^1, S^2 were formed outside the halo, and from them proceeded narrow, pale whitish streaks of light, resembling tails. These soon extended themselves so far as to meet in a point opposite the Sun, forming a great circle parallel to the horizon. At S^3 there appeared a third fictitious Sun, and shortly after a fourth at S^4. At P there was a small portion of a secondary halo.

Five parhelia.

(910.) Five parhelia, S^1, S^2, S^3, S^4, S^5, are shown in fig. 21, formed at the intersection of the several halos, S being the true Sun. This fine example was seen at Jackson in Tennessee, 19th August, 1825.

Six parhelia. The most complex yet recorded.

(911.) The most splendid parhelion of recent times was that seen at Gotha, on the 12th of May, 1824. The part of the sky occupied by the Sun was covered with small light Clouds, as well as very small white detached Clouds upon the sky opposite, and upon which the parhelion appeared, the phenomenon being always interrupted in the clear blue sky. The true Sun appeared at S, fig. 22, a circle of shining yellow light, S^1, C, S^2, S^3, surrounding it, its interior margin being red, and its opposite green. At S^1, S^2 two parhelia were seen a little out of the halo, and of the same elevation as the real Sun. These parhelia were very bright, and displayed all the colours of the rainbow, the red being as usual nearest the Sun. At S^3 appeared a third parhelion, less bright than the others. From A and B sprung an arc concentric with the halo S^1, C, S^2, S^3, whose radius, S A or S B, was double the radius of the first halo. The upper part of this arc glowed with the most brilliant colours, the red being towards the Sun. The remaining part of this halo dipped under the horizon. From the same points A and B, another arc A D F B proceeded, showing at D and F very lively colours, but at its extremities A and B, as well as in its middle portion D F, it was whitish. In these two arcs, the red colour was nearest the Sun, and the green on the opposite side. During a part of the time, an inverted arc D C F was seen in contact with the first halo at C; but at another interval of the phenomenon, two intersecting arcs appeared to spring from C, as in fig. 23. At this moment the point C displayed extraordinary brilliance, but no image of the Sun. Another circle K G L appeared also with very brilliant colours, touching the circle A H G I B at G, the red being on its outer border turned towards the Sun, and its inner circumference green. This circle was rather smaller than that surrounding the Sun. In the neighbourhood of G, the colours had extraordinary brilliance.

(912.) A large luminous circle, having the zenith Z for its centre, passed through the centre of the true Sun and the parhelia S^1, S^2 parallel to the horizon. Three other parhelia, S^4, S^5, S^6, appeared upon this last circle, the two first being each 90° from the real Sun, and the last 180°, or immediately opposite. Two luminous arches, O P and Q R, seeming to be portions of two great circles, intersected the fictitious Sun S^6 at right angles. Another observer saw these same arches crossing the horizontal arch nearly in a vertical direction, as fig. 24. During the continuance of the phenomenon, a portion of a circle, M S^3 N, was seen for a short time, and afterwards reappeared. This beautiful spectacle first appeared at 6½ hours A. M., and at five A. M. the thermometer was 36½° of Fahrenheit, so that at no great elevation in the atmosphere, the temperature must have been at the freezing point.

Seven parhelia.

(913.) At Kiaihta, in Siberia, on the 4th of February, 1829, at sunrise, the cold being very severe, luminous rays, known in that desolate region by the name of the Sun's ears, were seen on both sides of that luminary. At ten A. M. these rays changed into parhelia, an immense whitish column, similar to a comet's tail, issuing from the Sun towards the West, formed at length a perfect circle round the heavens. In the circumference of this circle were seven images of the Sun, pale and without rays, at nearly equal intervals from the Sun and from each other.

Singular phenomenon seen at Cape of Good Hope.

(914.) A singular phenomenon was seen by Mr. Fallows at the Cape of Good Hope, which Dr. Young regarded as fragments of coronæ, but which Brewster thinks must have been parhelia. On a clear evening, when the Sun's lower limb had just dipped the water's edge, seven luminous appearances of the same shape, but rather less than the real Sun, were perceived. These, at the moment the upper limb of the Sun came in contact with the horizon, appeared as bright points upon the water's edge, at which time one of them vanished instantaneously. This remarkable appearance is illustrated in fig. 25

Parhelia formed on some medium comparatively close to observer.

(915.) Parry observed, that though parhelia seem, to an observer placed nearly on a level with the sea, to be at a considerable distance from the eye, they are nevertheless found on ascending a gentle eminence to be formed on some medium comparatively close, perhaps only one or two miles distant.

Parhelia occur most frequently and exhibit greatest intensity of light at low elevations of the Sun. Hence seen in short days.

(916.) Parhelia occur most frequently, and exhibit the greatest intensity of light, at low elevations of the Sun. This is often particularly observable in the short days, when these phenomena assume a very brilliant appearance soon after sunrise, decrease in splendour towards noon, and resume their brightness as the Sun descends towards the West; continuing, however, distinctly visible the whole time, and being sometimes accompanied by a more or less perfect halo undergoing corresponding variations. Diversified, and most attractive as these beautiful phenomena really are, we must, nevertheless, hasten to the consideration of another part of the subject.

(917.) Not only is the Sun surrounded with beautiful phenomena of this sort, but the Moon also is attended by an appearance of the same interesting kind, denominated Paraselene. Dr. Trail records an interesting example of a wide halo, faintly exhibiting the prismatic colours formed round the Moon as a centre, a small portion of its circumference being cut off by the horizon. This circular band was intersected by two small portions of a larger circle, and which, if completed, would have passed through the Moon parallel to the horizon. At the points of intersection appeared two luminous discs tolerably well defined, equalling the Moon in size, but less brilliant. The Western paraselene had a coma directed from the Moon; that of the Eastern paraselene being much less distinctly marked, and soon lost in the adjoining segment of the larger circle. A representation of this phenomenon is given in fig. 26.

Paraselene, Dr. Trail's example.

Parry's;

(918.) At half-past six P. M. on the 1st of December, Captain Parry saw part of a circular halo, whose radius was 22° 52′ round the Moon. Part of a well-defined horizontal circle of white light, passing through the Moon, extended for several degrees on each side of her, and in the points where this circle intersected the halo, were paraselene. In the part of the halo immediately over the Moon, was another, much brighter, and opposite to it, in the lower part of the circle, another similar, but much more faint. About the same time on the following evening, two concentric circles were observed round the Moon, the radius of the smaller being 38°, and of the larger 46°. Upon the inner circle were four paraselene, strongly prismatic, and situated with regard to the Moon as on the preceding day. There was also a faint horizontal circle of white light passing through the Moon as before.

another of Parry's.

(919.) Parry gives also another case of a halo whose radius was 22° 30′, which had in it three paraselene, very luminous, but not tinged with the prismatic colours; and, on the following day, the same phenomenon occurred, with the addition of a vertical stripe of white light proceeding from the upper and lower limbs of the Moon, and forming with a part of the horizontal circle seen before, the appearance of a cross. This is represented in fig. 27. There was also at times an arc of another circle touching the halo, which sometimes almost reached to the zenith, changing the intensity of its light very frequently, not unlike the Aurora Borealis.

That seen by Hevelius.

(920.) One of the finest examples of paraselene was that seen by Hevelius at Dantzic, on the 30th of March, 1660, about A. M. The Moon A was surrounded by an entire whitish circle B C D E, in which were two mock Moons at B and D, displaying various colours, and shooting out at intervals long whitish beams. About two A. M. another circle surrounded the first, reaching to the horizon. At the summits of each of these circles, inverted, coloured arches were seen, the lower having the least curvature of the two. The exterior circle vanished first, then the largest of the inverted arches at C, and afterwards the other; and lastly, the inner circle B C D E disappeared. The diameter of the inner circle was 45°, and of the exterior 90°. See fig. 28.

Anthelion

Causes.

(921.) Amidst the unbounded diversity of the Clouds, there are some which reflect at times the Sun's image as from a surface of water, the phenomenon being hence called an anthelion. This appearance seems to result from two refractions and an intermediate reflection within the same icy crystal, causing a deviation of about $120^\circ + 22^\circ = 142^\circ$, and sometimes with two intermediate reflections, producing an angle of $60^\circ + 22^\circ = 82^\circ$

only; but it is difficult to account for the appearance of an anthelion exactly opposite the Sun, and for the unusual appearances which have sometimes been delineated as attending it.

Howard's exception of one.

Fine one seen from Shotover Hill.

(922.) Howard has frequently been able to trace the anthelion in greater or less perfection, on the perpendicular sides, or in the recesses between the crown and the foot of a large Cumulo Stratus, the Cloud being opposite to the Sun at a moderate elevation, and the upper sky clear. Under such circumstances, he says, we may sometimes discover at intervals, a broad spot of light, much brighter than the rest of the Cloud, and proceeding now and then to a momentary circular image, which is presently lost again by the change of form or direction of that part of the surface of the Cloud. Swinton, in the fine example which he saw of it from the top of Shotover Hill near Oxford, describes the anthelion to have been as large and bright as the true Sun, but not so well defined.

Glories.

Bouguer's example.

Howard's example.

Haygarth's splendid example.

Dr. Young's theoretical investigation.

(923.) Sometimes when we are standing on elevated ground, and our shadows are thrown on Clouds below, coloured circles, called *Glories*, may be seen surrounding our heads. When Bouguer and his companions were on Pichinca, a high mountain in South America, the Sun was just rising behind, and a white Cloud formed about thirty paces before them. On this Cloud each person saw *his own* shadow projected, but no other. Each shadow was perfectly defined, but the head was adorned with a kind of glory, consisting of three or four small concentric crowns having all the colours of the rainbow vividly displayed, the red being on the outside. At a considerable distance, a large white circle, 67° diameter, surrounded the whole. Howard and his family beheld a similar phenomenon at Folkstone; and he remarked, when any one of the party removed to a distance, that his shadow passed the halo that surrounded them, and appeared by itself, deprived of the glory; but the individual so removed, continued to see the glory surrounding his own shadow; those of the rest appearing to him without it. A beautiful example occurred to Dr. Haygarth, and is described in the IIId Volume of the *Manchester Memoirs*. His shadow was surrounded by coloured coronæ, and next to these were bright arches, wider than those of a rainbow. Dr. Young explains these phenomena by the interference of some of the portions of light regularly reflected within the minute drops of water, with other portions, incident at a different angle, but after an equal number of reflections, coinciding ultimately with them in direction; supposing only the Clouds in question to afford a number of these drops varying but little from each other in diameter. Dr. Young's investigations of this truly beautiful subject are well deserving the deepest attention. The Spectre of the Brocken is well worthy of attention, and is described in many popular Works.

Solar and Lunar Rainbows.

Rainbow.

Solar and lunar.

(924.) The rainbow cannot but be an object of especial interest to the Meteorologist, connected as it is with Clouds and all the phenomena of rain. Its optical properties, however, having been so ably described in another part of the *Encyclopædia*, we shall do little more than refer to some of its more remarkable appearances in this place. Rainbows may be divided into two classes, belonging to the Sun and Moon. With the ordinary appearances of the former we are all familiar though there are phenomena often which deserve in an especial manner the attention of the ardent Meteorologist.

Solar sometimes visible when Clouds are scarcely to be seen.

Only part of a rainbow sometimes seen.

Howard's remarks on formation and propagation of rain.

(925.) Although reflected upon a dark Cloud in its usual formation, as upon canvass, the rainbow seems, nevertheless, at times, to appear when Clouds are scarcely to be seen. Howard records an example of a few light Clouds beginning to appear in different quarters, but none over the place of the bow; nor was the falling mist that afforded it of sufficient density to obscure the sky. Sometimes a small portion only of a rainbow is exhibited on a few light Clouds. As these advance, the arch may increase, and the whole rainbow become at length complete. The other extremity may then fade and become reduced to a pale white, and the whole may eventually be reduced to this state. In an instance of this sort, Howard thought the rain was formed and propagated in the atmosphere with such rapidity as scarcely to afford time for the formation of drops, in the form of Cloud. Frequently small portions of the rainbow may be seen in different places.

Remarks on space between the primary and secondary rainbow.

(926.) When a brilliant rainbow with its complementary one are sometimes exhibited, the space included *within* the proper bow is perceptibly *lighter*, and that *without* it, extending to the outer bow, as much *darker* than the rest of the Cloud. Howard saw on a Nimbus a double rainbow on a ground of purple.

Third rainbow.

Other arches also in addition.

(927.) A third iris between the common ones, and not concentric with them, has also been seen, probably the result of reflection. Within the purple of the common rainbow also, arches have been seen, the first of which exhibited yellowish green, darker green, and purple; the second green and purple; and the third also green and purple. These were seen by Daval, and described by him in the *Philosophical Transactions* for 1749. He remarks, that these splendid additions of colour were not visible near the horizon, although the bow was very bright there. The supernumerary rainbows sometimes seen are particularly deserving the attention of the Meteorologist. Bülfinger saw three within the primary rainbow, the first of which was red, the second blue, green, and red, and the third dark red. A colourless bow may soon be followed by one having the usual colours.

Rainbows seen in the twilight.

Distorted rainbow.

Rainbow on the ground.

Rainbow by reflection.

Red and colourless rainbows.

Haze bow.

(928.) Rainbows have been seen in the twilight by reflection. The rainbow also has been seen distorted, probably by refraction. An hyperbolic rainbow on the ground has been witnessed, and also one inverted on the grass, formed by the drops of rain or dew suspended on spiders' webs in the fields. Two rainbows also have been seen, one by reflection from the sea. Red rainbows likewise occur. On the other hand, bows perfectly colourless have been seen in mists. On the clearing up of a considerable fog, and when the Sun was just visible, a rainbow of this sort was seen, whose breadth was about double that of an ordinary rainbow, and its colour grey. Near the ground the colour was brighter than towards the centre. Near the extremities of the bow were streaks of white of peculiar brightness. A haze bow of distinct and dazzling light was seen by Parry, having its edges softened off, and without any appearance of prismatic colours. The legs of the bow rose out of a bluish haze.

Halley's singular rainbow.

(929.) One of the most singular rainbows on record was that seen by Dr. Halley from the walls of Chester. A B C and D H E, fig. 29, were the primary and secondary rainbows as seen under ordinary circumstances.

Between these was another arch, A F H G C, rising from the intersections of the horizon with the primary rainbow, and in its upper part dividing the secondary bow into three nearly equal parts. This intermediate arch was coloured in the same way as the primary rainbow; but during the progress of the phenomenon, Halley saw the points F, G rise, and the arch F, G gradually contract, till the portions of the two bows between those points were identified. The intermediate and secondary bows having their colours contrary, produced, therefore, white between the points F and G.

Rainbows crossing each other.

(930.) Rainbows have been seen crossing each other nearly at right angles, as fig. 30.

Two primary rainbows with a secondary bow to each.

(931.) Mr. Sturges saw at Alverstoke, in the South-East, a dark Nimbus, at a time when the Sun shone brightly, near the North-West. Two primary rainbows appeared, not concentric, but touching each other, in the South part of the horizon, with a secondary bow to each, also in contact. Both the primary bows were very vivid for a considerable time, and at different times nearly equally so. The two sets of rainbows were unequal in size, the smallest ultimately vanishing, at which time the greater became a semicircle, the Sun being nearly setting. It was a perfect calm, and the sea, acting like a mirror, produced the smaller of the two rainbows by reflection. Edwards describes a rainbow which must have been formed by exhalations from the City of London, when the Sun had been set twenty minutes, and, consequently, the centre of the bow above the horizon. The colours were the same as in the ordinary rainbow, only fainter.

Rainbow formed by exhalations from London.

Lunar rainbow.

(932.) A lunar rainbow is but very rarely seen. It is sometimes white, and at other times its colours differ but little, excepting in intensity, from those of the solar rainbow. It is formed on the Nimbus, like the ordinary rainbow. Its brightness is frequently unequal; and in a case mentioned by Howard, its Northerly portion, near the Earth, had the colours very distinct; but in other parts they were scarcely distinguishable. A secondary arch was also perceptible, and very well defined. Its Northern extremity was coloured like that of the primary bow. The white portion vanished first. Sometimes a part only of the usual colours are lively and distinct. The lunar rainbow may first appear white, and afterwards develope colours.

Meteors.

Meteors.

(933.) But there are still other luminous appearances in the atmosphere demanding the attention of the Meteorologist, but to which we can only very briefly allude here. These are the meteors which occur under so many diversified circumstances, from the feeble shooting star which has but a momentary existence, up to the immense bodies which terrify whole nations by their magnitude, velocity, and splendour.

Shooting stars in the Torrid zone.

(934.) Shooting stars are far more abundant in the Torrid zone than elsewhere. Towards the morning of the 11th of November, says Humboldt, writing of Mexico, thousands of falling stars succeeded each other for four hours, in the Eastern sky, with the greatest regularity from North to South; and his illustrious brother traveller, Bonpland, remarked, that from the beginning of the phenomenon, not a space in the firmament equal to three diameters of the Moon, was to be seen free from these brilliant meteors. All of them left phosphorescent traces from five to ten degrees in length, which lasted seven or eight seconds. Some were seen even a quarter of an hour after sunrise. Humboldt found by collating different observations, that this brilliant appearance was seen over an extent of the Globe comprising 64° of latitude and 91° of longitude;—at the Equator, in South America, at Labrador, and in Germany, a space embracing 921,000 square leagues. Some of the Franciscan Monks situated at Maroa on the banks of the Rio Negro, marked the day on their Ritual.

(935.) Thirty years before the phenomenon witnessed by Humboldt and Bonpland, there was seen at the City of Quito, in the part of the sky above the volcano of Cayambo, so great a number of falling stars, that the mountain was thought to be in flames. The people assembled in the plain of Exido, where a magnificent view presents itself of the summit of the Andes. A procession was already setting out for the Convent of St. Francis, when it was perceived that the blaze in the horizon was caused by fiery meteors which ran along the sky in all directions, at an elevation of about twelve or thirteen degrees. And that this was not entirely a superstitious fear, but justified by past events, may be gathered from the fact, that during the earthquake which occurred in December 1809, at the Cape of Good Hope, "an uncommon number" of shooting stars fell. At Kingston in Jamaica, also, in November 1812, a large meteor appeared a few minutes previous to some alarming and tremendous concussions.

Connect of these phenom with ea quakes.

Small e tric exp sions in pics at of Marc

(936.) Between the Tropics, at the end of March, Humboldt informs us that the Southern region of the atmosphere is illuminated by small electric explosions, phosphorescent gleams, circumscribed by groups of vapour.

Remark number meteors Forster, Brande and Hu boldt.

(937.) According to Forster, the number of falling stars in the month of August in England, is to the number which fall in September as three to two. In all the other months, this phenomenon is three times less frequent than in August. There are months, however, in which Brandes has reckoned in our temperate zone only sixty or eighty falling stars in one night, and in other months their number has risen to two thousand. Whenever one is observed, says Humboldt, which has the diameter of Sirius or Jupiter, we are sure of seeing so brilliant a meteor succeeded by a great number of smaller ones. If the falling stars be very frequent during one night, it is very probable that this frequency will continue during several weeks. According to Brandes, the number of shooting stars which approach the Earth, surpasses those which recede from it;* and from this it appears that during the short time of their appearance, they are under the attractive influence of the Globe. Forster likewise observes that meteors are not seen below Clouds; nor are any, excepting the larger and brilliant kind, usually observed when thin Clouds are present. This may result from their formation requiring another condition of the atmosphere than what is necessary for the formation of Cloud. When a great meteor appeared near Benares, the sky was perfectly serene, nor had the vestige of a Cloud been seen eight days previous, nor were any observed for many days after. Benzenberg and Brandes consider them as belonging to the furthest limits of our atmosphere,

Meteo which proach Earth ceed th which cede fr

Abser Cloud

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* The actual passage of some of these meteors *upwards*, has led to the conclusion that they are not aerolites. M. Chladni, who at first looked upon them as such, has lately abandoned this supposition.

between the region of the Aurora Borealis and that of the lightest Clouds.

Greater part of velocity of shooting stars an illusion.

(938.) According to Brandes also, although shooting stars have a proper motion of their own, the greater part of their apparent velocity is an illusion, depending on the movement of translation of the Earth.* The continuance of their lucid trains is variable, enduring longer at some times than others. The light of meteors was considered by Lambert as a celestial signal, which might be employed for the determination of terrestrial longitudes.†

Large meteors.

(939.) But those grand and solitary meteors which occasionally occur, attract in the highest degree the attention of mankind. There are many recorded in history, some of doubtful tradition, and others which the hand of Superstition has moulded to her dark and suspicious forms.

Great one seen in 1718—19.

The large one seen all over Great Britain, Ireland, Holland, and the hither parts of Germany, France, and Spain, at the same instant of time, on the 19th of March, 1718—19, and described by the illustrious Halley in the *Philosophical Transactions*, may be referred to as a splendid and satisfactory example.

That recorded by Kepler.

In the *Ephemerides* of Kepler also, is an account of a meteor which was seen all over Germany, November 7th, 1623, O. S., and in Austria was heard to burst with an explosion like thunder. It would be easy to multiply instances.

Their general appearance varies considerably.

(940.) The general appearances of meteors of this kind seem to differ from each other very considerably, nor can we entirely attribute to the excited imaginations of observers, those great diversities by which their descriptions are characterised. It is very true, as Halley once pertinently remarked, that these splendid phenomena too often escape the observation of those best qualified to describe them; yet though destitute of those habits of admirable caution which the Philosopher after long and laborious discipline has acquired, we can see no good grounds for rejecting *in toto* all that has been recorded respecting them. By some it has been stated that they appear first as luminous balls, nearly round; that gradually becoming elliptical, tails are created as they ascend; that moving onwards, they at length undergo, in some part of their course, a remarkable change, resembling bursting; and that then proceeding no longer as an entire mass, they are at length divided into a great number of balls of unequal sizes, followed by trains like the original body. Under this form, the separated fragments may advance with a motion more or less uniform, perhaps emitting sparks, and continuing to afford a light more or less intense; the body either in its entire or disjointed state having described its immense trajectory in the sky, with a velocity so great, as to baffle almost entirely the judgment of the most accurate mind, until at length it is lost in the great concave itself, or proceeds beyond the furthest verge of the visible sky, to amaze and terrify the inhabitants of another land.

of [illegible]

(941.) Respecting the paths of these meteors we have no data to offer beyond the general observation of Blagden, that the major part have been observed to proceed from the North or North-West quarter of the heavens, and to move very nearly in the present magnetic meridian. This remark, however, is too vague to enable us to draw from it any definite conclusions; and we can therefore merely state, that their paths are described in general terms as either vertical or horizontal, but according to Edward Howard as travelling more frequently in the latter direction than the former; that sometimes they ascend and descend obliquely; sometimes move vertically in a part of their course, and horizontally in the remainder; at other times they rise and fall and make lateral deviations from a right line; on other occasions pursue an undulatory course, and sometimes a kind of spiral line; sometimes ascend to a small height and become stationary, which latter condition, however, may be only apparent, and sometimes exhibit distinct vibrations; that their motion appears also independent of the Earth's, being sometimes directly opposite to it; that sometimes they are formed far beyond the limits of our visible horizon, and make their appearance in or near it, ascend as they approach us, and undergo an apparent descent as they recede; and that sometimes they become objects only of telescopic vision, having been examined as such by Kirch* and the elder Herschel. At other times they appear suddenly in the higher regions of the sky, giving no notice of their approach until they dazzle us by their splendour. They are known to have described tracks of 1000 miles.

Capricious and singular forms attributed to them.

(942.) The forms of these meteors have been a fruitful subject for Superstition to dwell on, and ingenuity has been taxed to devise descriptions for them. They have been described as round and elliptical, as columns or pyramids of fire, comets, barrels, bottles, flasks, spears, paper-kites—a form very often named;—as a pear with its large end towards the Earth; truncated cones, trumpets, tadpoles, glass-drops, quoits, torches, javelins, goats, the Roman letter S, contorted Clouds, and many other objects; and from these diversities the numerous appellations given to them by the Ancients were borrowed.

Their trains or tails.

Colour.

(943.) Of their tails, the brightest portion seems to be of the same nature as the body itself, and an elongation of the matter composing it. The other, and commonly the largest portion of it, appears to be matter left behind, far less luminous than the other part;—sometimes described as a dusky red, sometimes of a pure grassy green, the tail seeming to partake of the colour of the body of the meteor; at other times as of a beautiful rose colour, tinged round the edge with blue;

Sparks, and forms.

sometimes emitting whitish and coloured sparks; sometimes long and undulating, sometimes twisted and appearing to lengthen from one end only,—again like a long white cloudy form, which may be gathered together and then slowly divided, one part, perhaps, remaining stationary, and the other moving off into some distant space.

Their excessive light. That of 1718—19.

(944.) Nothing, however, strikes the beholder more than the excessive light these meteors sometimes afford. In the great one of 1718—19, described by Halley, Sir

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* We thus arrive at a new proof of the motion of our Globe by observing a phenomenon so fleeting and inconstant as a shooting star!

† There would be some difficulty in this on account of our not knowing when to expect them; and supposing a night were selected when many meteors occurred, how should we be able to know that the *same* meteor was observed by separate persons? An example of the difficulty of observing even rockets, the firing of which had been previously arranged, may be gathered from Mr. Herschel's Paper in the *Transactions of the Royal Society* for 1826.

* Kirch was a diligent observer. He saw a meteor, whose light was most intense, dart downwards obliquely, which where it seemed to terminate, left two nodules visible only through his telescope. Herschel followed the great meteor of August 1783, for 20 or 25 seconds, with his telescope, during which it remained almost in one situation, within a few degrees of the horizon, confirming at once its great elevation and its long journey to the South.

Hans Sloane spoke of its light as being of so vivid and dazzling a lustre, as to compel him to turn his eyes several times from it. Hence people have read by the light of meteors; minute objects have been rendered visible on the ground in the darkest night, and larger ones many miles from the eye. The illumination is often so great as totally to obliterate the stars, to make the Moon look dull, and even to affect the spectators like the Sun itself. Many instances have occurred in which meteors have made a splendid appearance in full sunshine.

Colour of their light. Its effect on the Moon.

(945.) The colour of their light is various and changeable, but generally of a bluish cast, which makes it appear remarkably white. The Moon, when a great meteor occurred at Brussels, appeared quite red, but soon recovered its natural light. Meteors have been seen of a singularly pure grass green. That seen by Gassendi was inclosed in a luminous circle of colours like the rainbow. Prismatic colours have been seen in the body, in its tail, and even in the sparks of a meteor, and differently by different persons. By some they have been compared to the hues of gems. Sometimes the body of the meteor appears to consist of lucid and dull parts, perpetually changing, giving an idea of an internal agitation or boiling of the matter, and in other cases seeming like movable chains. It has also been compared to burning brimstone or spirits, to a pellucid ball of fire, and liquid pearl. Sometimes the light of a meteor appears to suffer a sudden diminution and then to revive, giving a notion of successive inflammation. Sometimes meteors and their trains have been seen white till near their extinction, when they have become a bright blue and tinged at their ends with red. Sometimes the light is described as perfectly white, and sometimes as bright blue.

Pure grass green. Prismatic colours. Light variable. Change of colour.

Meteors seen by day.

(946.) Of those seen by day, their observers have described them as running like fire, bursting like a rocket, and vanishing suddenly, leaving at times trains or columns of smoke. The latter phenomenon has been recorded by several observers.

Height of meteors.

(947.) The height of meteors is at present entirely conjectural. Halley computed the great one of 1718—19 to have been fifty miles high, but they must always appear much nearer than they really are from the effect produced by their great light, when seen without intervening objects. Sometimes their elevation is stated at from 20 to 100 miles. That seen by M. Antonio Brucalassi about five A. M. on the 2d of January near Arezzo, appeared only 100 paces from him, and 10 fathoms or less from the ground. M. de Luc has seen meteors from the tops of very high mountains, and in that lofty region they seemed to be at a very great distance. Such meteors as pass like a flash of lightning, must, where observers are prepared, afford great advantages for determining their height, as they must be seen nearly at the same moment of time and in the same place by different observers.

Meteors are attended with explosions. Description of sounds.

(948.) It seems beyond all doubt that these meteors at times are attended with explosions. Perhaps all are so; nor is the absence of sound in a particular locality any evidence that no sound is produced. An immense meteor may pass without any sound over a district, and in one adjoining a noise may be heard. Meteors may be formed in one region, pass over an immense interval, explode, and their fragments finally disappear in another very distant. The resulting sounds have been variously described, as dull, resembling the noise of a carriage like the discharges of musketry and cannon, whizzing, &c. Some of the recorded instances, however, must be received with caution. The explosion that attended the great meteor of 1716—19, rests, however, on very good evidence. It appeared like the discharge of a broadside at some distance; and in Devon and Cornwall it very sensibly shook the glass windows and doors. Mr. Cruwys, F. R. S. at Tiverton, had a looking-glass broken, which being loose, fell out of its frame by the concussion. Though it exploded over Tiverton, the sound was heard in London, notwithstanding an Easterly wind.

That of 1718—19

Their si unknown.

(949.) No adequate idea can be formed of the sizes of meteors. The Moon has very often been adopted as a standard of comparison for judging of their apparent dimensions; but this mode ought rather to be regarded as a general effect of the strong impression produced by such splendid objects on the mind, than as conveying any determinate idea of their size. Blagden, by supposing one to have subtended an angle of 30′, when it passed the zenith fifty miles high, inferred it was half a mile across, and the train ten or twelve times longer than the body. By some their diameters have been stated at more than a mile.

The dura tion of a meteor must be necessari very diffe ently stat

(950.) The duration of a meteor must be very differently stated, partly because some observers must necessarily have it in view a much longer time than others, partly from locality, and partly from one person in the same place having his attention called to it earlier than another. A meteor sometimes passing on in its full splendour becomes suddenly extinct, without any appearance of bursting or explosion. Meteors also have become suddenly extinct, and passing on revived again. Their duration is sometimes so short that good observers find it utterly impossible to state the direction in which it proceeds. Blagden said of a meteor, that he could not tell whether it proceeded *from* or *towards* the South-East.

The velo city of m teors.

(951.) Of their velocity we can give but very vague and uncertain notions. Blagden stated one to have moved twenty miles per second, which exceeds that of sound ninety times, and approaches to that of the Earth in its annual course. At this rate it must have passed over the whole of Great Britain in less than half a minute, and might have reached Rome, which there is some ground for supposing it did, within a minute afterwards. In seven minutes such a meteor would have traversed the whole diameter of the Earth. By others their velocity has been estimated at even thirty or forty miles per second. One seen by Gay Lussac remained stationary for five minutes. One seen November 7th, 1811, passed over 60° in the third of a minute. Meteors sometimes appear to start forward by successive fits.

(952.) The bodies actually discharged from these luminous Meteors, will be noticed under the head of STONES, (METEORIC,) in the *Miscellaneous Division.*

A few other Meteorological subjects which we are compelled to leave unnoticed here, will find their place in our Alphabetical arrangement, and the Reader will be easily guided to them by consulting the *General Index.*

GEORGE HARVEY.

Plymouth, July 31*st*, 1832.

FIGURE OF THE EARTH.

Since Astronomy first assumed the form of a Science, the inquiry into the Figure and dimensions of the Earth has always excited the interest of Philosophers. It can hardly be doubted that in the mind of a reflecting man there would always be a desire to know the nature of the Planet upon which he existed; but without Science of an exalted order, it would be impossible for him to gratify his curiosity. For the Astronomer, however, it was absolutely necessary to know something of the form of the Earth; and Astronomy alone gave the means of determining it. While the only observations of the heavenly bodies consisted in watching the rising and setting of the Sun and Stars, the form of the Earth was a matter of indifference; but when an attempt was made to reduce to a system the motions of the luminaries and Planets, it was necessary as a preliminary step to assume, and even to establish by something approaching to demonstration, a hypothesis on the Figure of the Earth.

At present the determination of the Earth's Figure possesses an interest of which formerly it was altogether destitute. The Astronomers of antiquity knew that the Earth is nearly spherical; they had also some not very correct ideas of its magnitude; and this was sufficient for their purposes. But the sphericity of the Earth, when thus established, was an isolated fact. It was proved by the impossibility of explaining certain phenomena on any other hypothesis; but it was not connected with any general theory which made this Figure a necessary consequence of the properties of matter. But by the discoveries of Newton the Figure of the Earth was shown to depend on the same theory which explains with such wonderful accuracy the motions of the Planets and their satellites. The investigations of the most profound Mathematicians have since been directed to its determination, from the Principles of Gravitation; and the labours of the most able experimenters have been employed in ascertaining it from actual observation; and the comparison of the results of theory and of observation shows that their agreement, though not perfectly exact, is sufficiently so to enable us to assert with confidence, that the Principle of Gravitation is well founded. Indeed, for one part of that Principle, (*viz.* that the attraction of a Planet is not a force directed to its centre, but is the resultant of all the forces directed to every one of its particles,) it may be considered as affording the most satisfactory proof that we can expect ever to have.

Under the head of the Figure of the Earth we propose not only to consider the theoretical form, and to give an account of the principal measures and their results, but also to explain the most remarkable phenomena depending on its Figure; namely, the variation of Gravity on its surface, and the disturbances in its own motion, and the motion of the Moon, occasioned by its deviation from the spherical form. And in connection with this subject we shall give a short account of the experiments which have been made to determine the comparative density of the superficial and the interior parts of the Earth. The whole may be considered as a collection of various classes of observations which have been made for the examination of that part of the Principle of Gravitation which asserts that "the attraction of a mass is the sum of the attractions of every one of its particles."

Section 1.—*History.*

General Principle of Meridian measures.

It was probably by observation of the form of the Earth's shadow, as seen in eclipses of the Moon, that the Figure of the Earth was first ascertained to be nearly spherical; and the necessity of an allowance for *parallax* in the Moon's declination would very soon teach Astronomers that the place of observation was not the centre about which the lunar revolutions were performed. But these remarks would in no degree enable them to form an idea of its magnitude. The method of determining the dimensions by measuring an arc of the meridian has been employed with no alteration of Principle from the time of the Alexandrian Astronomers to the present day. Let A, B, fig. 1., be two places of observation; A C, B C, lines perpendicular to the surface at those points: suppose these perpendiculars to intersect in C; let A F D, F B E, be horizontal lines; G A, H B, parallel lines, representing the directions of the visual rays from the celestial Pole, or from some very distant object, as the Sun or a Star. By observation of the angles H B E, G A D, (the altitudes of the Pole, or the Sun, &c.) their difference is known; that is, the difference of H B E and H K D, or K F B, which is equal to A C B. The length of the arc A B can be measured; knowing then the length of A B, and the angle A C B, and assuming A B to be a circular arc, the length of A C or B C can be immediately calculated. Instead of calculating the length of A C it is rather more convenient to calculate the length A M, which corresponds to an angle A C M of one degree; and this is usually called *the length of a degree on the Earth's surface.* It is plain that this process can be applied only when the vertical plane which passes through the two places, passes also through the body observed; and the observations must either be simultaneous, or must be of such a nature that a small error in the time (which in practice is inevitable) will produce no sensible error in the body's altitude. From these considerations it appears that A and B must be in the same meridian. If we assume the Earth to be spherical, we shall by this method find its radius; or if we perform the same operations in different parts of the Earth, and always find the same value for the radius, we may infer that the Earth is spherical.

This is the method pursued in the earliest measure of which we have any tradition, that of Eratosthenes. For we cannot hold with some writers that any real measure is alluded to by Aristotle, *De Cœlo,* lib. ii., when he

Estimation by Eratosthenes.

speaks of the circumference of the Earth as being 400,000 stadia, according to the opinions of the Mathematicians of his time. Eratosthenes, about 230 B. C., observed that at Syene, in Upper Egypt, the Sun was, as far as he could discover, exactly vertical at noon, on the day of the summer solstice; and that at Alexandria the Sun's zenith distance at the same season was 7° 12′. The former observation (according to Cleomedes) was made by remarking that the edges of a deep well threw no shadow on the bottom, the latter by the use of the *σκάφη*, a hemispherical bowl with a vertical style. These circumstances will be represented in fig. 1., if we suppose B H to be in the same straight line with C B, and G A parallel to B H, and the angle $N\,A\,G = 7° \, 12'$. He supposed Alexandria and Syene to lie in the same meridian, and reckoned their distance at 5000 stadia, which gave the Earth's circumference = 250,000 stadia. The length of the stadium here used is unknown, and it is unnecessary to point out the sources of error in this operation.

By Posidonius.

An estimation was also attempted (as the same author informs us) by Posidonius, who was contemporary with Pompey the Great. It appears to have been intended only as a rough guess, and is, in fact, much inferior in accuracy to that of Eratosthenes. He observed that the star Canopus was seen at Rhodes to just touch the horizon; at Alexandria he estimated its meridian altitude at $7\frac{1}{2}°$: the distance of the places was supposed to be 5000 stadia. This gave for the circumference of the Earth 240,000 stadia. In this measure it is merely necessary to observe that refraction was neglected, not being known; and that no accurate estimation could be formed of the distance of two places separated by the Mediterranean.

By Ptolemy

In the Astronomical Works of Ptolemy (who flourished about A. D. 137) we find no notice of the Earth's dimensions. He assigns as reasons for believing the Earth to be spherical, that eclipses of the Moon, as seen at different places on the Earth, take place at different times with reference to the noon of the places of observation; and that the differences of apparent times are proportional to the distances East or West. This, we believe, is the earliest notice of the Principle of deducing terrestrial longitude from the difference of the apparent times at which an eclipse of the Moon is observed. He remarks also that on going Northward, the number of circumpolar stars is increased, appearances which could not exist if the Earth were plane, or cylindrical. But in his Geography he tacitly assumes the Earth to be spherical, and uses constantly as the length of one degree 500 stadia. This estimation seems to have been made by Marinus the Tyrian, from observations of the latitude of very distant places, and from the rough measures of the distance made by sailors and merchants.

The dark Age which followed the overthrow of the Alexandrian School, put a stop to all speculations on the Figure of the Earth. It was not till the Empire of the Caliphs had extended over the greatest part of the civilized World, and the Works of the Greek Astronomers had been translated and studied by the Arabs, that another attempt was made to measure an arc of the meridian. Abulfeda relates that Abdalla Almamoun, who begun his reign at Bagdad A. D. 814, having fixed on a spot in the plains of Mesopotamia, ordered one company of Astronomers to go Northward and another Southward, measuring the distance by rods, till each should find their alteration of latitude, or alteration in the altitude of the Pole, to be one degree. One party found the distance 56 miles of 4000 cubits, the other $56\frac{2}{3}$ miles; the latter was adopted as preferable to the former. The length of the cubit, however, is not known.

Measure by Almamoun.

By Fern

Seven hundred years elapsed before another estimation was attempted, and the scene was then shifted to Western Europe. Fernel, a Parisian, born in 1485, (according to Lalande, *Mém. Acad.* 1787,) published in 1528 the account of a measure made in the neighbourhood of Paris. On August 25, he observed the Sun's meridian altitude at Paris; he went Northward one degree, as nearly as he could judge, and on August 29 again observed the Sun's meridian altitude. His observations were made with a triangle, (not a quadrant,) of which one side, eight feet in length, was vertical; another side of the same length was movable round the point of connection with the first, and carried sights; the third side measured the distance between the other two, and was graduated as a line of chords to every minute of the quadrant. (This is the instrument which Ptolemy describes as proper for the observation of the Moon's parallax.) On applying to the Sun's altitudes the proper correction for change of declination, he found that his latitude had increased one degree. The distance was calculated from the number of turns made by the wheel of his carriage. The length of an arc of meridian of one degree, thus found, (56,746 toises,) agrees very well with the length given by modern observations, (about 57,060 toises.)

By Snel

The next measure (that of Snell) is distinguished by a very great improvement in the manner of measuring, —the substitution of trigonometrical operations for the actual measurement of the whole distance by the application of rods or perambulators. This method is partly described in our Treatise on TRIGONOMETRY, section 9; and will be illustrated more fully in a succeeding section of the present Essay. The account of Snell's measure was published at Leyden, in 1617, under the quaint title *Eratosthenes Batavus de Terræ ambitûs verâ quantitate, &c. a* Willebrordio Snellio *suscitatus*. He measured a base of 326.4 Rhinland perches, and two bases of verification of 348.1 and 166 perches, (each perch of 12 feet.) The length of the first base was, however, in reality concluded from a base of 87.05 perches; for the calculated length is used, though it differs a little from the measured length. His angles were observed with quadrants and semicircles. Thus he found the meridian distance between Alcmaer and Bergen-op-Zoom = 33,930.2 perches. Their latitudes he found to be 52° 40′ 30″, and 51° 29′. From this he found one degree of meridian = 28,473 perches. Between Leyden and Alcmaer he found 1° = 28,510; finally he fixed upon 28,500. As he was careful to compare his standard with the standards of other nations, this measure was readily reduced to French toises, and it gave 1° = 55,100 toises. A recalculation and reobservation of the latitudes by Muschenbroek in 1729, gave 1° = 57,033 toises. Another measure was effected (we believe in nearly the same locality) by Blaeu, or Cæsius; it was said to agree in its results with Picard's, but we are unacquainted with the details.

In 1637 was published, *The Seaman's Practice, contayning a fundamentall Probleme in Navigation experimentally verified, namely touching the Compasse of the Earth and Sea, and the Quantity of a Degree in our English Measures, &c.;* by Richard Norwood, Reader

By Norwood.

of the Mathematicks. In this Work most of the older measures are mentioned. It is stated, also, that a Mr. Edward Wright had observed the dip at Mount Edgecumbe, and had inferred the semidiameter of the Earth to be 18,312,621 feet. The author then states, that on June 11, 1633, with a sextant of more than five feet, he observed the Sun's meridian altitude near the Tower of London to be 62° 1′; and on June 6, 1635, he found the Sun's altitude at York to be 59° 33′; the difference of latitude 2° 28′. The distance was measured with a chain of 99 feet; the bearings of different parts of the road were observed with a circumferentor, and the measures reduced by a Table. Part of the distance he paced, in which he says he came through custom very near the truth. The number of chains was 9149; from which he found 1° = 61,199 fathoms.

By Riccioli.

About the same time a trigonometrical measure was attempted in Italy by Riccioli. Beginning with a base of 1094 Bolognese paces, he found the meridional distance from a point near Bologna to Modena 20,439 paces; the difference of latitudes he found to be 19′ 25″. The angles were measured with an instrument nearly similar to that of Fernel. From this it appeared that 1° = 63,159 paces, = 61,478 toises, or 65,521 fathoms. This measure has been universally condemned. The Geodetic part was not well conducted, and the Astronomical observations were far below the general science of the Age. It has been remarked, also, that Riccioli was persuaded of the accuracy of the Greek estimations, which (in his interpretation) were considerably greater than the later measures seemed to show. The part of his Works (*Geographia*) which comprehends this measure, contains an interesting account of all the methods of determining the Earth's dimensions which were known at that time, and of all the estimations which preceding Mathematicians had formed.

The method which he appears to have thought superior to all the others, is that of observing from each of two stations the depression of the other; and he instances some observations of his own which give nearly the same value for a degree as that which we have cited. The principle of this method will be readily understood by supposing P and Q, fig. 1, to be two elevated stations, and remarking that if the angles C P Q, C Q P, be observed, P C Q will be found by subtracting their sum from 180°; and the distance P Q being measured, the lengths C P, C Q, are easily calculated.

By Picard.

In 1669 the trigonometrical measure of Picard was commenced; and it was in every respect superior to all that had preceded it. It is true that it was not free from errors: an error of six toises was committed in the measure of the base; and his differences of latitude were vitiated by his ignorance of aberration, &c.; but, by a happy chance, these errors almost balanced each other. The extremities of his arc were Sourdon, (near Amiens,) and Malvoisine, (near Paris.) His base was 5663 toises; his base of verification 3902 toises. The difference of latitude of Malvoisine and Sourdon was found to be 1° 11′ 54″; and when the measure was extended to Amiens, the difference of latitude of Malvoisine and Amiens was found to be 1° 22′ 55″. The corresponding arcs were 68,430 and 78,850 toises; the first gave for the length of an arc of 1°, 57,064 toises, the second 57,057; the mean is 57,060 toises = 60,812 fathoms. The Astronomical observations were repeated in 1739 by Maupertuis, Clairaut, &c.: they found 1° = 57,183 toises.

Huygens's ideas of centrifugal force.

In 1673 appeared the Work of Huygens, entitled *De Horologio Oscillatorio*. In this, for the first time, were found correct notions on the subject of centrifugal force. It does not appear, however, that these were applied to the theoretical investigation of the Earth's form before the publication of Newton's *Principia*.

Newton's investigation of the Earth's form.

In 1666 Newton appears to have first entertained the idea of Gravitation. It is remarkable that, at this time, he seems to have been unacquainted with the measures of Norwood and Snell; and considering the length of a degree, according to the usual estimation, to be sixty miles, he was induced, by the disagreement of his calculations from this estimation, to lay aside his theory of Gravitation. For the Moon's parallax being known, that is the proportion of the Earth's radius to the radius of the Moon's orbit (supposed a circle) being known, the force of Gravity on the Moon was found by Newton's law; and the periodic time was also known; and from these data, and the theorems of Huygens and Newton relating to motion in a circle, it was easy to calculate the radius of the circle in which it moved, and consequently (from the proportion above mentioned) the radius of the Earth: if this were not the same as the radius given by the measures, Newton's law could not be true. The measure of Picard enabled him to establish the theory; and it is this measure that is used in the *Principia* published in 1687. In this wonderful Work a prodigious step was made towards the theory of the Earth's form. Combining the theory of centrifugal forces with the properties of fluids, Newton showed that the Earth must be not spherical but spheroidal; that its equatorial diameter must be longer than its axis of revolution; and he actually calculated the proportion of the diameters, on the supposition that the Earth had been in the state of a homogeneous fluid, to be 229 : 230. With regard to this astonishing investigation we shall merely state, that though defective, it is not erroneous; it is one of the many instances in which Newton has obtained a correct result by means apparently quite inadequate. He showed, also, that Gravity must be less at the Equator than near the Poles; and this served to explain a very remarkable fact that had lately been observed. In 1671 Richer, who had been sent by the French Government to Cayenne for the purpose of conducting a series of Astronomical observations, found that his clock, which had been regulated to mean time at Paris, lost more than two minutes every day. Similar facts were afterwards observed by Varin and Deshayes on the coasts of Africa and America; and in all cases the alteration of the clock's rate was much greater than any that could be caused by the change of temperature.

Variation of Gravity on the Earth's surface.

Newton's explanation of the precession of the Equinoxes.

But the most remarkable of Newton's inferences is, perhaps, his explanation of the precession of the Equinoxes. This motion of the Earth's axis was discovered by Hipparchus, (B. C. 150;) and all succeeding Astronomers had recognised its existence. Eighteen centuries after its discovery, it was shown by Newton to be a consequence of the attraction of the Sun and Moon on the Earth's equatorial protuberance. Having shown that the attraction of a distant body on a satellite would produce a retrograde motion of its nodes, he observes that if we first suppose a number of satellites to revolve in one plane, and then suppose them to be connected in such a manner as to become a solid ring revolving in its plane, we shall still have a retrograde motion of the nodes: and if the Earth be fixed within the ring, the motion of the nodes, though less than before, will still be retrograde; and the transition from this case to that of an oblate spheroid is sufficiently obvious. The calculation which Newton has attempted to found on this reasoning is in some respects erroneous; but the explanation is, perhaps, one of the strongest proofs of genius. Indeed, if at this time we might presume to select the part of the *Principia* which probably astonished, and delighted, and satisfied its readers more than any other, we should fix without hesitation on the explanation of the precession of the Equinoxes.

Huygens's investigation of the Earth's form.

In 1690 was published Huygens's Treatise, *De Causâ Gravitatis.* It contains an investigation of the figure of the Earth, supposing the attraction upon every particle to be directed towards the centre, and to be always the same at equal distances from the centre. This supposition, it will be remarked, is directly opposed to one part of the Principle of Gravitation, namely, that which states that every particle attracts every other particle. The ratio of the axes is found in this manner to be 578 : 579.

J. Cassini's Meridian measure.

In 1684 J. D. Cassini (second of that name) commenced a trigonometrical measure of an arc of meridian in France, taking Picard's base as a foundation and proceeding Southward. It was intended that this should serve as a basis for a map of France; and the more accurate measure which was afterwards executed on the same line was used for that purpose. Some interruption took place, (on the death of the Minister Colbert,) but it was at length finished in 1701. The series of triangles was then extended Northward to Dunkirk, and this part was finished in 1718. A base of 7246 toises was measured near Perpignan, and one of 5464 toises near Dunkirk. The difference of latitudes of Paris and the Southern extremity, Collioure, was found to be 6° 18′ 57″, and the distance 360,614 toises; whence 1° = 57,097. The difference of latitudes of Paris and Dunkirk was found to be 2° 12′ 9″.5, and the distance 125,468 toises; whence 1° = 56,960. It appeared, then, that the degrees shortened in going from the South to the North; and this seemed to indicate that the Earth was a prolate spheroid, the ratio of its axes being nearly 95 : 96. A conclusion in such direct opposition to Newton's theory, now extensively received, excited a great sensation among the Mathematicians of Europe. The accuracy of the measure and the certainty of the conclusion were sustained by Cassini; who, as well as his father and his son, seem to have been firmly convinced that the Figure of the Earth was elongated. To settle the point, a degree of a parallel was measured in 1734, extending from Strasburg to St. Malo. This, also, when compared with the others, seemed to lead to the same conclusion. It was alleged, however, that the difference of longitude of these stations was determined only by some ancient eclipses of Jupiter's satellites, and that no reliance could be placed on them. To escape from this state of doubt, it was determined that an arc of meridian, and if necessary, one of parallel, should be measured near the Equator, in the comparison of which with the arc measured in France, the inevitable errors of observation would produce a smaller effect; and this is the origin of the celebrated expeditions of the French Academicians.

Measure of an arc in Peru.

Every facility being afforded by Louis XV., in May, 1735, MM. Bouguer, Godin, Lacondamine, and others, sailed for South America; they then crossed the Isthmus of Darien, and sailed to Peru. The difficulty of measuring an arc of parallel, and its inutility, (as on any hypothesis it would differ little from an arc of meridian in France,) were so strongly represented by Bouguer, that it was laid aside. But the great valley between the two principal chains of the Andes was found so favourable for operations in the direction of the meridian, that they effected, with the assistance of some Spanish officers, the measure of an arc of three degrees. The Northern limit was a place called Tarqui, 2′ North of the Equator; the Southern extremity, Colchesqui, was in South latitude 3° 4′. A base of 6272 toises was measured in the neighbourhood of Quito, and near the Southern extremity; and a base of verification of 5259 toises near the Northern extremity. No other measure* has been conducted under such extraordinary circumstances of locality. The lowest point of their arc was at an elevation of a mile and a half above the level of the sea; and, in some instances, the heights of two neighbouring signals differed more than a mile. At some places the danger was considered by the inhabitants to be so great, that public prayers were put up in the churches for their safety. The indolence and ill-will of the natives troubled them much; they were even in danger of losing their lives in a popular tumult; and to crown the whole, the instruments by which they were to determine their difference of latitude were found to be not trustworthy, and the corrections of the places of the stars were not to be relied on. The former difficulty they overcame by an ingenious reconstruction of their instruments, the latter by simultaneous observations at the two extremities of the arc. Their final result was that the whole length of the meridian arc, reduced to the level of the lowest station, was 176,945 toises, corresponding to a difference of latitudes of 3° 7′ 1″; and, therefore, that the length of an arc of one degree was 56,767, or reduced to the level of the sea 56,748. The arc was extended about twenty minutes by Godin; but this addition is generally supposed to have been less accurately measured than the other parts. In this expedition an attempt was made by Bouguer to observe the effect of the attraction of Chimborazo; of this we shall speak hereafter. For the complete details of this very interesting measure we must refer the reader to Bouguer's and Lacondamine's accounts; the former is the more amusing and more interesting to speculative Mathematicians, but the latter will be found by practical Astronomers to be the more instructive.

Measure of an arc in Sweden.

Before the return of this party (who, in consequence of their dissensions, separated as quickly as possible, and regained Europe by different ways) another measure had been imagined and completed. Maupertuis, Clairaut, Camus, Lemonnier, and Outhier reached the Gulf of Bothnia in July 1736. They had expected to be able to make use of the islands in the Gulf for the stations of a trigonometrical measure; but they found them so low, and so near the shore, that they were obliged to give up this part of their plan. But the valley of the river Tornea, which passes by the town of the same name, seemed to offer a favourable line of country; and this was accordingly chosen. The stations (as in the Peruvian measure) were on the hills on each side; and the river gave them some facilities for

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* From this remark we ought, perhaps, to except a part of the survey of an arc of parallel made in the present century, in which the principal chain of the Alps was passed.

History.

the conveyance of their instruments. In the prosecution of their work great inconvenience was sustained from the cold, the birds of prey, &c. but the greatest of all from the tormenting flies and gnats. The fogs also, with which some of the hills were continually enveloped, increased the difficulties of the observations; in some instances they waited ten days on the top of a hill before they could see one of their signals. After sixty-three days of great fatigue they reached the mountain Kittis, which was fixed on for the Northern extremity. The latitudes were observed with a sector made by Graham. On their return to Tornea, the river being frozen, a base was measured on the ice nearly in the middle of the arc, but no base of verification was measured. The result being somewhat different from what they had expected, the latitudes were reobserved, and some angles of the triangles, which had before been omitted, were observed. The final conclusion was that the difference of latitudes was 57′ 29″,6, and the length of the arc 55,023 toises; whence an arc of 1° = 57,422. In this expedition, as well as in that to Peru, observations were made to ascertain the length of the pendulum vibrating seconds; and they all agreed in showing that Gravity increased in going from the Equator towards the Pole. For a complete account of this measure we must refer the reader to Maupertuis, *La Figure de la Terre*.

Before the return of Bouguer and Lacondamine, the whole of the French arc of meridian was remeasured by J. Cassini, his son Cassini de Thury, and Lacaille. The operations of this measure are the subject of the Work entitled *La Méridienne vérifiée*. On measuring new bases and making new observations of every kind, the cause of the original difficulty was soon discovered. The measure of Picard's base was erroneous by about $\frac{1}{1000}$th part of the whole, and this error had affected one part only of the arc. Some inaccuracies both Astronomical and Geodetical were found to exist in Cassini's measure. The late improvements in Astronomy, particularly the discovery of aberration and nutation, enabled the new observers to give much greater exactness to the Astronomical observations. They observed the latitudes of five points, and thus obtained, in fact, four arcs of meridian. Between Perpignan and Rodéz the length of an arc of one degree was found = 57,048 toises; between Rodéz and Bourges 57,040; between Bourges and Paris 57,071; and between Paris and Dunkirk 57,084. In the course of this measure an arc of parallel was measured across the mouth of the Rhone. From a station near Cette in Languedoc, and from Mont St. Victoire in Provence, the explosion of gunpowder at a church between them was observed; and from the difference of apparent times the difference of longitudes was found to be 1° 58′ 19″. The length of the arc of parallel in latitude 43° 32′ included between the two meridians was 76,599.6 toises. The comparison of this arc with the arc of meridian from Perpignan to Rodéz gave an ellipticity $\frac{1}{168}$.

The comparison of any two of the three arcs in Peru, in France, considering the whole as one arc, and in Sweden, showed that the degrees increased in going towards the Pole, and that, consequently, the Earth's Figure was flattened at the Poles. But when all three were considered, a singular difficulty occurred, which we may be permitted to say is not yet wholly removed. The comparison of the Peruvian and French arcs gave an ellipticity of nearly $\frac{1}{314}$; that of the Peruvian and Swedish arcs gave $\frac{1}{213}$ for its value. If, then, the measures were accurate, it was impossible that the Earth's Figure could be elliptic: and Bouguer actually proposed, as the only hypothesis which would satisfy observations, that the increase of the lengths of degrees was proportional to the 4th powers of the sines of latitude, and that the proportion of the axes was 178 : 179. This would indicate a Figure projecting at middle latitudes above the elliptic spheroid with the same axes.

To avoid interruption in our account of several important measures, we have omitted to mention some interesting deductions from the theory of Gravitation made about the same time. These we shall now describe.

Maclaurin's investigation of the Earth's form.

The first important addition to the theory of the Earth was made by Maclaurin. The Academy of Paris proposed as a subject for the Prize Essay in the year 1740, *The Tides*. Three admirable Essays were sent, by Euler, D'Alembert, and Maclaurin: the last is generally considered as one of the most elegant Geometrical investigations that was ever made. Most of the operations can be applied, with very slight alterations, to the investigation of the Figure of the Earth, supposing it a homogeneous fluid; and the author has indicated the principal results which can be obtained by this application. In this Treatise it was proved for the first time, that the oblate spheroid is a form of equilibrium; and the equation was given by which the ellipticity can be found when the proportion of the centrifugal force at the Equator to Gravity is known. This equation is transcendental; but, by an approximate solution when the centrifugal force is small, it was shown that the ellipticity (that is the proportion of the excess of the equatorial diameter above the polar diameter to the latter) is $\frac{5}{4}\times$ the ratio of the equatorial centrifugal force to the equatorial gravity; which in the case of the Earth is $\frac{5}{4}\times\frac{1}{289}=\frac{1}{230}$; and that Gravity at the Pole is greater than Gravity at the Equator, by the same proportion of the whole; and, also, that in going from the Equator to the Pole, the increase of Gravity is as the square of the sine of the latitude. These results are the same as those of the imperfect theory of Newton.

Clairaut's investigation.

In 1743 was published Clairaut's *Figure de la Terre*. This is the most valuable Work that has been written upon this subject. The same theory has since engaged the attention of the most distinguished of the modern Mathematicians, and finally of Laplace; and though the form of the investigations has been much varied, very little has been added to the results. The nature of the equilibrium of fluids is first explained. The only condition which had formerly been assumed as sufficient for the equilibrium of fluids was, that the force at the surface should be perpendicular to the surface, or that the pressure produced by the fluid in two canals of given form, terminated at one extremity in the same point, and at the other extremity in the surface, should be the same. Bouguer first showed that both of these conditions were necessary, or something equivalent to both. Clairaut has shown upon what the possibility of equilibrium depends; and he has applied these principles to the discovery of the form of equilibrium of a fluid on the

Clairaut's theorem.

lowing suppositions: 1st, that the Fluid is homogeneous, with a spheroidal nucleus of different density; 2dly, that the whole mass is fluid and heterogeneous. The form which makes equilibrium possible in all the variety of cases which these suppositions include, is, approximately, an elliptic spheroid; the ellipticity is different according to the law of density, &c., but in all cases the following theorems are true: 1st, the increase of the length of degrees and of Gravity, in going from the Equator to the Poles, is as the square of the sine of latitude; 2dly, the sum of the ellipticity, and of the ratio of the whole increase of Gravity to the equatorial Gravity, is $\frac{5}{2}$ × the ratio of the centrifugal force at the Equator to the force of Gravity. The last of these theorems (one of the most important that has ever been discovered) is usually called by the name of its inventor. It is evident that, in conjunction with the former, it gives the means of determining the Earth's ellipticity from observations of the comparative force of Gravity at any two places.

Nutation discovered by observation and explained by theory.

In 1747 Bradley discovered the nutation of the Earth's axis. This had been alluded to by Newton as a consequence of his theory, but no notice seems to have been taken of his theoretical prediction. As soon, however, as the fact was established, it was treated theoretically by Mathematicians: among the best of the Treatises upon nutation may be reckoned D'Alembert's *Recherches sur la Précession, &c.*

Measure of Boscovich.

In 1750 Boscovich and Le Maire, two Jesuits, measured an arc from Rome to Rimini. Their measures were made with the pace, the measure of the Country; but it was carefully compared with the French toise, so that their results could be expressed in terms of the same standard which had already served for so many measures. A base of 6139.5 toises was measured on the Via Appia; and a base of verification of 6037.6 toises by the sea-side near Rimini. The meridian distance was found = 161,253.6 paces = 123,221.3 toises; and the difference of latitude 2° 9′ 47″, whence 1° = 56,966.3 toises. This, when some corrections were applied, was reduced to 56,979; the mean latitude 42° 59′ The whole of this measure passed over a mountainous country.

Measure of Lacaille.

In 1752 Lacaille, who had been sent to the Cape of Good Hope to make Astronomical observations, finding the circumstances of the country favourable for a trigonometrical survey, measured an arc of 1° 13′ 17″.3, which he found = 69,669.1 toises; whence 1° = 57,037. The length of his base was 6467 toises. See *Mém. de l'Acad.* 1751. This arc presents a remarkable anomaly. According to this measure, a degree in the South hemisphere, whose mean latitude is 33° 20′, is equal to a degree in the North hemisphere, whose mean latitude is about 45°. The known ability of the observer almost forbids the supposition of an error in the observations; and we have no grounds for conjecturing the cause of such a deviation from the law which seems to apply to the other arcs.

The measures described in the next three paragraphs were undertaken, we believe, at the suggestion of Boscovich.

Liesganig's measure.

In 1762 Liesganig, a Jesuit, began the measure of an arc of meridian passing through the Observatory of Vienna. See the *Dimensio graduum Viennensis et Hungarici.* Every care apparently was taken to ensure the correctness of this measure. The Vienna fathom was compared with a French toise furnished by Lacondamine and Lacaille; the iron quadrant of 2½ feet, with which the angles of the triangles were observed, was repeatedly examined in all possible ways; the sector, for observation of latitude, (which we shall afterwards describe,) was on the most improved construction; the observations of latitude were sufficiently numerous; in every triangle, except one, Liesganig assures us, that the three angles were observed; and all the calculations were reexamined. The base (between Neustadt and Neunkirch) was of 6288 toises; the base of verification in Marchfeld was of 6388 toises. The concluded meridional distance of Sobieschiz and Varasdin (the North and South extremities) was 172,796 Vienna fathoms; and the difference of latitudes 2° 56′ 45″.5, whence 1° = 58,655 Vienna fathoms = 57,077 toises. Yet in spite of all these apparent securities, there appears reason for rejecting this measure. The principal objections to it may be seen in Zach's *Correspondance Astronomique, &c.* vol. vii. In the first place, it is certain that the star which Liesganig has put down as μ Draconis is not μ Draconis, but some other star; possibly 85 ι Herculis, which Zach mentions. This would occasion no error, (as the same star was observed at different stations,) except in consequence of taking erroneous reductions. In the next place, Zach (who possessed some of Liesganig's manuscripts, and who recalculated some of the observations) affirms, that many of the observations had been altered to produce greater apparent agreement. And, lastly, it appears from a repetition of part of the survey by the Austrian officers in the beginning of the present century, that in one of Liesganig's triangles it was impossible, and apparently had always been so, to observe one of his stations from another; and, in fact, when the value of one of the angles, as given by him, was compared with the sum of two angles, which ought to be equal to it, observed by the Austrian officers, a difference of 3° was found. This triangle is the last but two to the South; up to this the surveys agree within a few toises, but after this they sometimes differ in the situation which they assign to a station by more than 2500 toises. It would seem that a signal was mistaken; a similar accident happened to Snell; and there is reason to think that it has also occurred in the survey of England made under the direction of the Master-General of the Ordnance. Another arc was measured by Liesganig on the plain of the Theiss, from Kistelech in the North to Czuroch, near Petervaradin, in the South. The length was 59,990 Vienna fathoms; and the difference of latitudes 1° 1′ 34″.5; whence 1° = 58,453 = 56,881 toises. Several circumstances prevent us from attaching much value to this measure; one is, the great number of small triangles which the nature of the country compelled him to use.

Reasons rejecting

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About the same time Beccaria, a Jesuit, assisted by another of the same Order, measured a degree in the plain of Lombardy. The measure of Boscovich crossed the Apennines, and its extremities were on the sea-coasts; this of Beccaria (undertaken, as we have mentioned, at the suggestion of Boscovich) was carried over a flat country, and terminated at both extremities at the foot of lofty mountains. It was supposed that if the inequality of the country produced in the measure of a degree any sensible irregularity, the effects, in these two measures, would be of opposite kinds, and that the difference in the length of a degree would be such as to give a good idea of their magnitude. An iron toise, which had been compared by Lacondamine and Lacaille with the toise used in the measure of the arc in Peru, (commonly called the toise of Peru,) was Beccaria's standard. His instruments were in almost every respect similar to those of Boscovich. The length of the base was 6501 toises; the meridional distance from Andratæ, the Northern extremity, to Mons Regalis, (Mondovi,) the Southern extremity, was 64,890 toises. The difference of latitude was found to be 1° 7′ 44″.7; whence 1° = 57,468 toises; a quantity much greater than other measures would have led us to expect. The mean latitude is 44° 57′. An account of this measure was published under the title of *Gradus Taurinensis*. In the surveys made by the French officers during their occupation of this Country, and in the repetition of the observations for the latitudes of the stations by MM. Plana and Carlini, some discrepancies have been found, which would seem to show that the credit of this measure is rather doubtful.

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In 1764 Messrs. Charles Mason and Jeremiah Dixon, who had before been engaged by the Royal Society for some important Astronomical observations, were employed in settling the boundaries of Maryland and Pennsylvania in North America. The line which they traced out in the peninsula between Chesapeak Bay and Delaware Bay seemed so favourable for a meridian-measure, that, on their representation, the Council of the Royal Society furnished them with standards and instructions, and procured the loan of a sector belonging to Mr. Penn. An account of the measure is given in the *Phil. Trans.* for 1768. This measure differs from all others made since the time of Norwood in this respect,—that no triangles were used, but the whole line (about 100 miles) was measured with rods. These rods were compared with a five-feet brass rod made by Bird. The whole length was found to be 538,067 feet, and the difference of latitude 1° 28′ 45″; whence 1° = 363,763 feet = 60,627½ fathoms. It had been found by a comparison of standards (*Phil. Trans.* vol. xlii.) that the English fathom $= \frac{107}{114} \times$ French toise; whence one degree was inferred to be 56,904½ toises. But after a new comparison of the toise and fathom, made under the inspection of Dr. Maskelyne, and after applying some small corrections, this was reduced to 60,625 fathoms, or 56,888 toises. The mean latitude was 39° 12′.

The anomalies in these measures were so considerable, that it appeared highly desirable to discover whether the attractions of mountains could have a sensible effect in altering the direction of Gravity. If in consequence of the proximity of a mountain the plumb-line was drawn from the position which it would otherwise have maintained, it is evident that the point of the heavens which corresponded to the zenith of a station, as determined by Astronomical observations, would not be the same as if the mountain did not exist. If, for instance, a mountain were at L, near the point A, in fig. 1, and drew the plumb-line towards L, the apparent direction of Gravity, instead of A C would be A c, and the apparent horizontal line instead of A D would be A d; the difference of latitudes, or the angle A C B, would be changed to A c B, and the length of the radius of curvature of the meridian would be changed from A C to A c. On account of the influence of these effects on the determination of the Figure of the Earth, as well as for the important confirmation which might be given to the Principle of Gravitation, it was to be wished that the attraction of a mountain might be ascertained by direct experiment. This had been attempted by Bouguer and Lacondamine in Peru; but the cold was so intense that it was difficult to make the observations with sufficient accuracy, and other circumstances were not favourable. Instead of observing the zenith distances of a star on opposite (North and South) sides of the mountain, they could only fix on two stations on the South side, one close to the mountain, the other at a distance of 3570 toises from the first, and 505 South of it. The effect of attraction appeared to be 7″.5; but they considered the conclusion almost unworthy of credit. In 1772 (see *Phil. Trans.* 1775) Dr. Maskelyne proposed to repeat the experiment. He pointed out Whernside in Yorkshire as a mountain on the opposite sides of which the attraction would be sensible; or he thought that the defect of matter in the valley between Helvellyn and Skiddaw, (or rather Saddleback,) in Cumberland, producing an effect of the opposite kind, might be sensible in the same kind of observations. Mr. Charles Mason was sent out to examine these, or to look for a hill proper for the purpose: these were finally rejected, and Schehallien was chosen. This is a mountain near Blair Athol, in Perthshire; it is a narrow ridge running East and West, in a comparatively flat country, and about 2000 feet higher than the general level. In 1774 the observations were made. The meridional distance of two stations on the North and South sides was found, by survey, to be 4364.4 feet, which on any estimation of the Earth's dimensions would give for the angle A C B, fig. 1, (C being considered as the centre of the Earth,) a quantity differing very little from 42″.9. The apparent difference of latitude, from Dr. Maskelyne's observations, given either by the 40 observations calculated by Maskelyne, or from the whole mass of 337 calculated by Zach, (*L'Attraction des Montagnes, &c.*) is 54″.6. The difference, or 11″.7, is the sum of the attractions which the mountain exerted in opposite directions on the plumb-line, when placed on opposite sides of the mountain. The mean density of the Earth, calculated on the theory of Gravitation from this attraction, and from an accurate survey of the mountain, was found by Dr. Hutton, (*Phil. Trans.* 1778, 1811, and 1821,) to be about 1.8 × density of Schehallien, or about 5 × density of water.

Attempt to ascertain the attraction of a mountain in Peru.

Observations on the attraction of Schehallien.

The arc of meridian which had been traced so accurately through France, served for a foundation to the surveys for a very accurate map of France. Nothing of this kind had been done in England, excepting a survey of part of the Highlands, commenced in consequence of the Rebellion of 1745. The disastrous wars of the last century prevented our Government from extending the map. In the year 1785, Cassini de Thury presented to the Royal Society a memorial on the uncertainty in the difference of longitude of Greenwich and Paris; and proposed that the English and French Mathematicians in concert should determine, by Geodetic operations, the distance, measured along an arc of parallel. This was assented to, and the English survey was placed under the superintendence of General Roy, the French under that of Count Cassini, (fourth of that name,) Mechain, and Legendre. We believe it may fairly be said that in this, as in other grand experiments, though we began later than our continental neighbours, we conducted our operations with a degree of accuracy of which, till that time, no one had dared to form an idea. For the measure of the first base on Hounslow Heath, in 1784, deal rods

Junction of the observations of Greenwich and Paris.

(which had been used in all preceding measures) were rejected, and glass tubes were used. These were afterwards laid aside, and a steel chain was employed in the measure of a base of verification on Romney Marsh. In 1791 the base on Hounslow Heath was remeasured with the chain. The description of the mode of measuring the bases (*Phil. Trans.* 1785, and *Account of Trigonometrical Survey*, vol. i.) was translated into French by M. Prony. The angles of the triangles were observed with a large theodolite, made by Ramsden; and this is the first instrument with which the spherical excess of the sum of the three angles above 180° (a quantity that rarely exceeds 3″ or 4″) was observed. The French part of this survey is remarkable also, as the first instance in which the newly-invented repeating-circle was used in extensive operations. Whether this invention has contributed to the accuracy of Astronomical determinations, we may be permitted to doubt; but it can hardly be doubted that it is an excellent instrument for Geodetic operations. The chain of triangles formed by the English observers, extended from the neighbourhood of London to Dover, and across the channel to Calais, and some neighbouring stations; the French triangles joined these with the chain of triangles formerly observed in the meridian of Paris, in the neighbourhood of Dunkirk.*

The object originally proposed in this survey was now attained; but it will readily be imagined that advantage was taken of such an admirable commencement for an equally excellent extension. An accurate survey of the whole Kingdom was commenced; several bases of verification were measured, and in the course of the survey, an arc of parallel between Beachy Head and Dunnose was measured in 1794, (by reciprocal observations of azimuth, a method which we shall hereafter describe,) and an arc of meridian from Dunnose to Clifton in Yorkshire, in 1802. The latitudes were observed with a large zenith sector made by Ramsden. The first of these arcs gave for the length of a degree of longitude in the parallel of 50° 37′ 7″.3, 38,818 fathoms; the second gave for the length of a degree of meridian in latitude 52° 2′, 60,820. This arc of meridian was divided into two parts, nearly equal, by the station of Arbury Hill; the arc from Dunnose to Arbury gave for one degree in latitude 51° 25′, 60,864; that from Arbury to Clifton gave for one degree in latitude 52° 50′, 60,766. These partial arcs present the same anomaly as those in France; the degrees appear to diminish in going towards the Pole. (See *Account of Trigonometrical Survey*, and *Phil. Trans.* for various years.)

English arc of parallel.

English arc of meridian.

Origin of the new French measure.

In 1791 the National Convention of France wishing to fix on a new standard of linear measure, determined (in the true spirit of the Revolutionary Philosophy) to select one which could not be considered as belonging to one nation rather than to another, but which might claim to be esteemed a standard for all the World. The length of the pendulum vibrating seconds at a given place had been pointed out by Picard as the best practical standard; but this did not suit the expanded ideas of the French legislators. They considered that the length of the seconds' pendulum varied on varying the place of experiment; but that, assuming the Earth's surface (at least the Geometrical surface at which if channels were made communicating with the sea the water would find its level) to be an exact surface of revolution, the length of the quadrant of meridian passing through every place would be the same. The length of the quadrant of meridian passing through the Observatory of Paris was therefore to be ascertained, and one ten-millionth part of this was to be called the *mètre*. It is almost unnecessary to add, that the idea of replacing a lost standard by means of an extensive Geodetic measure is perfectly chimerical; and that the only practical method (still subject to some uncertainty) is by ascertaining the length of the seconds' pendulum, which it is presumed, in the same place, does not vary from one Age to another. The measure was undertaken by Delambre and Mechain, and is described in the *Base du Système Mètrique;* a Work which cannot be too strongly recommended to the perusal of all who wish to be acquainted with the methods pursued in an extensive survey by the ablest general observers and practical Mathematicians of the Age. The difficulties with which they had to struggle were very great, arising principally from the disturbed state of the Country, and, as they approached to a termination, from the depreciation of the assignats. Fire-signals at night are preferable to all others for the operations of a survey; but these it was impossible to employ, as the people would have supposed them to be counter-revolutionary signals. In the choice of day-signals, and in procuring permission to erect and to observe them, they experienced sometimes the most serious, and sometimes the most ludicrous obstacles. It was generally necessary to receive the sanction of the popular assembly of each town through which they passed; and in many cases Delambre found himself obliged to give to the collected inhabitants a sort of Lecture on Geodesy. When a great part of their labour was completed, they were dismissed from their office for not having sufficiently distinguished themselves by their hatred of Kings. They were, however, allowed to complete the arc which they had originally intended to measure; following the course of the former measures, and using, in many instances, the same signals from Dunkirk to Barcelona. The part South of the Pyrenees was measured by the permission and with the assistance of the Spanish Government. As soon as the details of the measures could be collected, they were laid before a committee consisting of scientific deputies from several continental nations. It was there determined to proceed on the assumption, that the Earth is an exact elliptical spheroid, and to calculate its ellipticity, its dimensions, and the length of the quadrant, from a comparison of the arc newly measured with the arc measured by Bouguer and Lacondamine in Peru. The ellipticity adopted was $\frac{1}{304}$, and the mètre was fixed at 443,296 lines. The latitudes were observed at Dunkirk, Paris, Evaux, Carcassone, and Montjouy, near Barcelona. The arc was thus divided into four partial arcs, of which the middle latitudes were 49° 56′, 47° 31′, 44° 42′, and 42° 17′, and which gave respectively for the length of one degree, in toises, 57,082.7, 57,068.8, 56,977.8, and 56,946.6. This survey was afterwards extended by Biot and Arago to the Island of Formentera, near Minorca; the mean latitude of the additional arc was 40° 1′, and the length of one degree 56,956.4. The mean latitude of the whole arc, from

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* The whole of this measure has been repeated; the English part under the direction of Captain Kater, the French under that of M. Arago. See *Phil. Trans.* 1828.

Figure of the Earth.

Cavendish's experiments on the attraction of leaden balls.

Formentera to Dunkirk, is 44° 51′, and the mean length of the arc of one degree 57,006.6.

In 1798, a beautiful series of experiments was instituted by Mr. Cavendish, for determining the attraction of metallic balls. The observations on Schehallien had shown, that the attraction of a mountain was certainly appreciable; but it required much artifice, and great experimental delicacy, to make the attraction of a sphere of lead, eight inches in diameter, distinctly sensible. This, however, was effected, and so completely that the comparison of the effects of this attraction with the effects of the attraction of the Earth, enabled him to infer the proportion of the Earth's mean density to the density of lead; and of course to the density of water. The result is very nearly the same (*Phil. Trans.* 1798 and 1821) as that given by the Schehallien experiment.

Earth's ellipticity discovered by the motion of the Moon.

Nearly at the conclusion of this century the investigations of Laplace (*Mécanique Céleste*) furnished us with a curious method of determining the ratio of the Earth's axes. He showed that, in consequence of the Earth's oblateness, the Moon's motion would not be the same as if the Earth were spherical; and that *two* of the resulting irregularities would rise to such a magnitude as probably to be sensible. From the accurate observations of the Moon made at Greenwich, the existence of these inequalities has been detected, and their magnitude (about 8″ each) has been ascertained with tolerable certainty. They indicate an ellipticity of nearly $\frac{1}{300}$.

We have mentioned that the ellipticity of the Earth, (assumed to be an elliptic spheroid,) given by a comparison of the degree in Peru with that in France, was not the same as that given by the comparison of the degree in Peru with that in Sweden. The only inference to be drawn from this was, that the assumption was false, and that some such form as that stated by Bouguer must be the true one. No new measures had since been made which could be considered as decisive on this point: the measure in Peru was made with very great care: the accuracy of that in France had been confirmed by the late measure; and, as the only possible explanation, it was thought that the circumstances under which the Swedish measure was made, were not perhaps so favourable to accuracy. To set this at rest the arc was remeasured, and extended in both directions by Svanberg, in the years 1801, 1802, 1803. The details will be found in his very elegant Work entitled *Exposition des Opérations faites en Lapponie, &c.* In this survey the peculiarities of the new Astronomical School of France were pushed to an extent to which the boldest of their proposers had hardly ventured. The French standard and the French graduation alone were used; no instrument but the repeating circle was employed; the labour which English observers would have used in making good single observations was by Svanberg bestowed on the infinite repetition of angles; the imagination was taxed to discover the best manner of combining the observations in order to obtain the result which, according to the theory of chances, would be most probably correct. The methods of calculation were principally taken from Delambre. The base was nearly the same as that measured by the Academicians; the triangles, as far as the survey of the Academicians extended, were the same; those which Svanberg added were not so favourably circumstanced. The latitudes of his extreme stations, Mallorn and Pahtavara, were 65° 31′ 30″.265, and 67° 8′ 49″.83; the distance 180,827 metres = 92,778 toises; whence 1° = 57,196 toises. (Maupertuis had found 1° = 57,422 toises.) The result of this measure seemed at once to destroy the difficulty which had so long troubled Philosophers; in fact, the arcs already mentioned agreed pretty well with the new arc in giving an ellipticity rather less than $\frac{1}{300}$.

Svanberg's arc in Sweden.

History.

But how is the difference of the two measures to be explained? The geodetic measures, as far as they went together, agree very well; the latitude of Tornea, as determined by Maupertuis, agrees perfectly with the observations of Svanberg; the latitude of Kittis was not observed by Svanberg. It is much, very much, to be regretted that the Swedish Astronomer did not repeat the observations at the only place where an important error could be feared.

Zach's observations on the attraction of Mimet.

In 1810 an attempt was made by Baron de Zach to show that the attraction of a mountain called Mimet, near Marseilles, was appreciable. (See his Work, *L'Attraction des Montagnes, &c.*) He observed the latitude of a station on the Southern face of the mountain, and that of the small island Planier: and he calculated the difference of latitudes from the distance found by survey. The attraction of the mountain appeared to produce in the latitude an error of 1″.98. It has been shown, we think satisfactorily, by Arago, (*Conn. des Temps*, 1819, *Additions*,) that the repeating circle used by Zach (as appears from other observations made with it) was not good enough for an operation of such extreme delicacy. We may add, that as the stars observed were all on the same side of the zenith, a change in the constant error of the circle would produce an error in the result without affording any means of discovering its amount.

Arc of meridian measured by Lambton in India.

In the present century an arc has been measured by Colonel Lambton in the Peninsula of India, which, for length and accuracy, must be considered, we think, as exceeding those of all the arcs yet measured. (See *Asiatic Researches* for various years, or *Phil. Trans.* 1818.) The instruments and the methods of calculation were similar to those used in the English survey. The latitude of Punnæ, the Southern station, (near Cape Comorin,) was found to be 8° 9′ 38″.39; that of Daumergidda, the Northern extremity, 18° 3′ 23″.53; the meridional distance 598,609.98 fathoms, or 680 miles. By observing the latitudes of two intermediate stations, this arc was divided into three partial arcs, whose amplitudes were 2° 50′ 10″.54, 4° 6′ 11″28, and 2° 57′ 23″.32; and whose lengths were 171,516.8, 248,188.5, and 178,904.7 fathoms; which give respectively for the length of a degree 60,472.8, 60,487.6, and 60,512.8 fathoms. A comparison of these values with those determined by the French, English, or modern Swedish measures, gives for the ellipticity a quantity rather less than $\frac{1}{300}$. An arc of parallel was also measured in the same manner as the English arc between Dunnose and Beachy Head; but the geographical situation of the place is highly unfavourable to the use of this method.

The first instance, we believe, in which instantaneous fire-signals were used to determine the difference of longitude of two places, for the purpose of comparing it with the distance measured on an arc of parallel, and

Extensive arc of parallel measured in Europe.

thus determining the radius of the parallel of a given latitude, was that in which Cassini de Thury and Lacaille measured an arc across the mouth of the Rhone, and observed the explosion of gunpowder at one intermediate point. In the years 1821, 1822, and 1823, the difference of longitude of Marennes (near Bourdeaux) and Padua was determined by this method. This extensive arc was divided into six partial arcs, and the difference of longitudes* of the extremities of each was ascertained independently of the others. The observers were MM. Brousseaud, Nicollet, Plana, and Carlini. The geographical distance of both extremities from the frontiers of Savoy and Piedmont, had been ascertained by a survey conducted by the French engineers. Considerable difficulty was found in connecting these parts of the survey, as it was necessary to select several stations on the very crest of the Alps. This was at last effected in that part of the chain which lies between the passes of Mont Cenis and Mont Genèvre; accessible stations were found, though one was more than 11,000 feet above the sea. These triangles of junction were surveyed by a mixed commission of Austrian and Piemontese officers. The result (*Conn. des Temps*, 1829, *Additions*, and *Opérations Géodésiques et Astronomiques en Piémont et Savoie*) is that the length of a degree of parallel in latitude 45° 43′ 12″, is 77,865^m·75. A comparison of this arc with the principal arcs of latitude seems to show that the ellipticity is about $\frac{1}{280}$. At the same time the arc measured by

Remeasurement of Beccaria's arc.

Beccaria was remeasured, and the latitudes of the stations reobserved. The result differs from Beccaria's, but not so much as to remove the anomaly in that measure.

The arc of parallel between Beachy Head and Dunnose, measured by General Roy, was used to fix a scale of longitudes in the Ordnance map of England. It was suspected that the scale was erroneous, but it was only in 1823 that this was clearly established. Dr. Tiarks,

Connection of the measure of parallel in England.

by carrying several chronometers backwards and forwards between Dover and Falmouth, found that the difference of their longitudes was incorrect, to the amount of 4″ of time; the difference of longitudes given by the map being smaller than that given by the chronometers. It was necessary, therefore, to diminish the value of a degree of parallel, as determined by Roy's observations; and the degree so diminished agrees much better with those obtained from other measures.

Besides these measures which have been undertaken expressly for the purpose of ascertaining the Earth's dimensions, others have been made in which the principal object was the mapping of the country, and from which the Earth's dimensions have been incidentally deduced, when the latitudes of extreme stations as observed, have been compared with the latitudes as calculated on assumed dimensions. We have great doubts of the accuracy, in general, of the observed latitudes; and we have not, therefore, thought these operations worthy of a particular mention. Several, undoubtedly, ought to be excepted from this remark; we may mention in particular the survey lately made connecting Göttingen and Altona, in which we believe that the latitudes were observed with Ramsden's sector, but of which the details have not reached us.

Moder perime with th pendul for the riation Gravity

In the present century, and at the termination of the last, a great number of expeditions have been undertaken, of which one of the principal objects has been to determine the length of the seconds' pendulum at different places. We cannot here give any detailed account of them, and shall merely mention the following. Observations at places in a great extent of latitude in the Spanish expedition of 1789; (*Conn. des Temps*, 1816, *Additions*;) observations by the French at various places in France and England; (*Base du Système métrique*;) observations made in the voyages of Captains Ross and Parry; (see the accounts of those voyages, and *Phil. Trans.*;) observations by Captain Sabine at a number of places in almost all practicable latitudes, undoubtedly the best series of observations yet made; (*Account of Experiments, &c.*;) observations made in the voyages of Freycinet and Duperrey; (accounts of the voyages, and Additions to the *Conn. des Temps*;) observations made by Captain Kater at several places in Great Britain, and by Captain Hall, Sir Thomas Brisbane, Mr. Goldingham, and others, in various parts of the world. (*Phil. Trans.* various years.) The pendulum experiments, especially those of Captain Sabine, appear to indicate a greater ellipticity than is given by the measures.

In our account of the various measures and experiments which are used to determine the Figure and constitution of the Earth, it is possible that we may have omitted some of inferior note. We believe, however, that we have included all upon which any reliance can be placed for aiding us in a most difficult and delicate inquiry.

Section 2.—Theoretical Investigation of the Form assumed by a Revolving Fluid on the Principle of Gravitation.

Physic theory.

(1.) It will be proper to commence this investigation by a repetition of the explanation given in our Treatise on HYDRODYNAMICS, of the conditions of equilibrium of a Fluid of which different points are acted on by different forces acting in different directions.

(2.) We shall suppose that some point is taken as the origin of a system of rectangular coordinates, and that the coordinates of any point are called x, y, z; and that the force R, which acts on the Fluid at that point, is resolved into three forces parallel, respectively, to the three axes, (see MECHANICS, § V.) which are called respectively X, Y, Z. These forces (or the single force of which they are parts) are of the kind called accelerating forces; they are not pressures, but, like Gravity and all kinds of attraction, they produce pressure by acting upon some mass, and the pressure so produced is proportional to that mass. We ought, in strictness, to state it thus: the force which we call R acting on the mass dm produces the pressure $R\,dm$, and this is resolved into the pressures $X\,dm$, $Y\,dm$, $Z\,dm$, parallel to the three coordinates x, y, z.

Condi the eq brium Fluid.

(3.) Now if the Fluid is at rest, we shall not disturb its rest by enclosing a part of it in tubes. Suppose then that in the fluid mass, fig. 2, we place several tubes extending from the surface to the small quantity of Fluid enclosed in a box at the point A: and now let us consider the state of the Fluid in these tubes, &c. as

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* The English reader who wishes to be acquainted with the best method of determining differences of longitude by fire-signals, is referred to an admirable paper by Mr. Herschel, *Phil. Trans.* 1826, on the determination of the difference of longitude of Paris and Greenwich.

if the surrounding mass did not exist. The action of the forces on the different parts of Fluid in the tube C D A will produce a pressure on the Fluid at the place A; that in the tube E A, or C B A, will also produce a pressure there. Now the characteristic property of Fluids (HYDRODYNAMICS, § II.) is, that the pressure produced by the Fluid in E A, will be transmitted by the Fluid at A, in such a manner as to cause the same pressure upwards (estimated by the pressure on a given surface) at the bottoms of the tubes C B A, C D A. If, then, the pressures produced by the Fluids in these tubes be less than that produced by the Fluid in E A, the Fluid will be forced up them; if greater, it will descend, forcing a portion of the Fluid up A E; both which conclusions are inconsistent with our supposition of rest. It is necessary, therefore, that they be equal; and thus we obtain as the condition necessary for equilibrium; the pressure produced by the Fluids in all imaginary canals from the surface to any given point of the Fluid must be equal.

(4.) This condition is also sufficient for equilibrium. For if we take small tubes as F G, H G, to any part of the tube E A, the Fluids in these, in consequence of this condition being satisfied, will have no tendency to disturb the Fluid in E A; from which it appears, that the equilibrium of the Fluid in E A does not depend on its being enclosed in a tube: and the same applies to any other point of the Fluid.

Expression for pressure of a Fluid.

(5.) The condition can now be reduced to a mathematical form, for which purpose we must find an expression for the pressure produced by the Fluid in a tube. Take a very small portion of the tube, as B b, and construct a parallelopiped of which B b is the diagonal, and whose sides B c, c d, d b, are parallel to the coordinates x, y, z, respectively. As these sides are the differences between the coordinates that correspond to the point B, and those that correspond to the point b, let them be called dx, dy, dz; and call B b, the increase of the length of the tube in proceeding from B to b, ds; call the section of the tube, expressed in square units of surface, K; and the density of the Fluid in that part of the tube, expressed by the weight of one cubical unit, ρ. Then the solid content of the tube B b is K ds; the weight of the Fluid contained in it is K ρ ds: the action of the force X upon this causes the pressure K ρ X ds in the direction B c. Resolve this (MECHANICS, Art. 29.) into two pressures, one of which is parallel to B b, the other perpendicular to it. The latter of these will only cause a pressure on the sides of the tube, and therefore is to be neglected; the former will cause a pressure in the direction of the tube, and will therefore add to the pressure of the Fluid. Its value is $\mathrm{K}\rho\mathrm{X}\,ds \times \cos b\mathrm{B}c = \mathrm{K}\rho\mathrm{X}\,ds \times \frac{\mathrm{B}c}{\mathrm{B}b}$ $= \mathrm{K}\rho\mathrm{X}\,ds \times \frac{dx}{ds} = \mathrm{K}\rho\mathrm{X}\,dx$. This is the pressure which it causes on the surface K; and therefore on a surface 1 it would cause the pressure $\rho\,\mathrm{X}\,dx$. Similarly it would appear that the pressure caused by the action of the force Y would be $\rho\,\mathrm{Y}\,dy$; and that caused by the force Z would be $\rho\,\mathrm{Z}\,dz$. The sum of these, or $\rho(\mathrm{X}\,dx + \mathrm{Y}\,dy + \mathrm{Z}\,dz)$, is the quantity by which the pressure of the Fluid is increased between B and b; and therefore it is, in common language, the differential of the pressure. The whole pressure is the integral of this, and is therefore $\int\rho\,(\mathrm{X}\,dx + \mathrm{Y}\,dy + \mathrm{Z}\,dz)$.

(6.) Now the condition of equilibrium requires that the pressures produced by the Fluids in the tubes C B A, C D A, should be equal, or (since this is to be the case for tubes of any form) that the pressure should be independent of the form of the tube. Now the form of the tube will be defined by two equations, one of which will express y in terms of x, and the other z in terms of x; so that, assuming at pleasure a value of x, we can find corresponding values of y and z. For every different form of the tube, y and z will be expressed in different functions of x. And since the density at any point is known from a knowledge of its situation, ρ is a function of x. On substituting these values in the quantity $\rho\,(\mathrm{X}\,dx + \mathrm{Y}\,dy + \mathrm{Z}\,dz)$ it will have the shape $\phi\,(x)\,dx$, the integral of which is of the form $\psi\,(x)$; putting a and e for the values of x at A and C, and integrating between these limits, the pressure will be $\psi\,(a) - \psi\,(e)$. Now this expression clearly is not the same for all forms of the function ψ, that is, it is not the same for all forms of ϕ, or it is not the same for all figures of the tube; and therefore when it is necessary to integrate $\rho\,(\mathrm{X}\,dx + \mathrm{Y}\,dy + \mathrm{Z}\,dz)$ in this manner, the equation of equilibrium cannot be satisfied.

Mathematical condition of equilibrium.

(7.) But there is one case in which $\rho\,(\mathrm{X}\,dx + \mathrm{Y}\,dy + \mathrm{Z}\,dz)$ can be integrated without expressing y and z in terms of x; it is when $\rho\,(\mathrm{X}\,dx + \mathrm{Y}\,dy + \mathrm{Z}\,dz)$ is explicitly a complete differential of some function of x, y, and z. In this case, supposing the integral to be $\chi\,(x, y, z)$, and putting a, b, c for the values of x, y, z, at the point A, and e, f, g for those at the point C, the pressure will be $\chi\,(a, b, c) - \chi\,(e, f, g)$. Here the expression is the same whatever be the form of the tube; and thus we get for one condition of equilibrium, that $\rho\,(\mathrm{X}\,dx + \mathrm{Y}\,dy + \mathrm{Z}\,dz)$ must be explicitly a complete differential.

Form of external surface necessary for equilibrium.

(8.) Here we have compared the pressures produced by the Fluids in two tubes drawn from the same point of the surface C. If, however, we take another tube E A from another point of the surface, and call l, m, n the coordinates of E, the expression for the pressure which the fluid in it produces will be $\chi\,(a, b, c) - \chi\,(l, m, n)$. This must be the same as the former expression; hence $\chi\,(l, m, n)$ must be the same as $\chi\,(e, f, g)$. Applying this to all points of the surface we find that, l, m, n being the coordinates of any point of the surface, $\chi\,(l, m, n)$ must be constant; or putting x, y, z instead of l, m, n, and observing that $\chi\,(x, y, z)$ is the integral of $\rho\,(\mathrm{X}\,dx + \mathrm{Y}\,dy + \mathrm{Z}\,dz)$, the external surface will be defined by making this differential $= 0$, or $\mathrm{X}\,dx + \mathrm{Y}\,dy + \mathrm{Z}\,dz = 0$. And this is the second equation of equilibrium.

Relation of forces when the Fluid is homogeneous.

(9.) Suppose the Fluid to be homogeneous, or ρ, the density, to be constant and equal to k; then we must have $k\,(\mathrm{X}\,dx + \mathrm{Y}\,dy + \mathrm{Z}\,dz)$ a complete differential, or $\mathrm{X}\,dx + \mathrm{Y}\,dy + \mathrm{Z}\,dz$ a complete differential. Now it is remarkable that this condition is satisfied by the only attractive force (Gravitation) whose laws are accurately known to us, as well as by the centrifugal force of which we shall presently speak. For, let the mass of one attracting point be dm, its coordinates a, b, c, the coordinates of an attracted point x, y, z, the distance between them r, so that

Satisfied by Gravitation and centrifugal force.

$$r = \sqrt{\overline{x-a}|^2 + \overline{y-b}|^2 + \overline{z-c}|^2}.$$

Then the attraction in the direction of r, on the principle of Gravitation, will be represented by $\frac{dm}{r^2}$; that in the direction of x will be $\frac{dm}{r^2} \times \frac{x-a}{r} = dm \times \frac{x-a}{r^3}$; those in the direction of y and z, $dm \times \frac{y-b}{r^3}$, and $dm \times \frac{z-c}{r^3}$ Hence $X = dm . \frac{x-a}{r^3}$, $Y = dm . \frac{y-b}{r^3}$, $Z = dm . \frac{z-c}{r^3}$, and $X\,dx + Y\,dy + Z\,dz$

$$= dm . \frac{\overline{x-a}.dx + \overline{y-b}.dy + \overline{z-c}.dz}{(\overline{x-a}|^2 + \overline{y-b}|^2 + \overline{z-c}|^2)^{\frac{3}{2}}},$$

which is a complete differential (the integral is $\frac{-dm}{\sqrt{\{\overline{x-a}|^2 + \overline{y-b}|^2 + \overline{z-c}|^2\}}}$). The same will be true for the forces produced by the attraction of any other attracting point; and therefore for the forces produced by the sum of all the attractions of different points. The centrifugal force (as we shall show hereafter) is proportional to the distance of the point on which it acts from an axis, and acts in the direction of a line perpendicular to the axis, and passing through the point; whence it is easily found that, supposing the axis of z to be the axis of rotation, and the force to be $m \times$ distance, the force in the direction of x will be mx, and that in the direction of y will be my, that in the direction of z, 0; therefore $X\,dx + Y\,dy + Z\,dz = m\,(x\,dx + y\,dy)$, which is a complete differential, its integral being $\frac{m}{2}(x^2 + y^2)$.

Form or surface of equal density when the Fluid is heterogeneous.

(10.) If ρ be not constant, and if $X\,dx + Y\,dy + Z\,dz$ be a complete differential, and $= dq$, then the quantity in Art. (7.), which must be a complete differential, is $\rho\,dq$. This can only be true when ρ is a function of q; and, consequently, so long as q does not vary, ρ must remain without variation. That is, if the fluid be heterogeneous, the surface which limits a stratum of any given density is defined by the equation $q = c$. Let p be the pressure; then $dp = \rho\,dq$, and $p = \int \rho\,dq$, which is some function of q, as $\phi\,(q)$; and if q' be the value of q at A, and q'' the value at the surface, p at $A = \phi\,(q') - \phi\,(q'')$. From this (as in Art. 8.) it appears that $\phi\,(q'')$ must be constant, or q'' must be constant, at the external surface; and thus it appears that the external surface, as well as any surface which separates strata of different density, is defined by the equation $q =$ constant. It appears, also, that $p = \phi\,(q')$ — constant, whence q' is a function of p, and ρ, which is a function of q', is also a function of p; that is, where p is the same, ρ is the same. Conversely, where ρ is the same, p is the same, provided* that the Fluid consist of indefinitely thin strata of densities varying from any one to the next in contact with it.

The same equation holds if the density depend on the pressure.

(11.) From this conclusion we derive this remarkable inference, that if we suppose the density to depend on the pressure, the equations of equilibrium will not be in any degree altered. For that supposition would only require that ρ should be the same where p is the same, which is already secured by the conclusion just mentioned.

Attracti… entirely …rected t… centre.

(12.) *Example.* Suppose the only forces which act on each particle of a heterogeneous Fluid to be these; an attraction (not to every other particle but) to the centre, varying inversely as the square of the distance from the centre; and the centrifugal force resulting from rotation round an axis passing through the centre. (This is nearly the same as Huygens's supposition.)

Let A C B, fig. 3, be the axis, C the centre, C M, M N, N P, the three coordinates of a point P, one of which (N P or z) is parallel to the axis; join C N, C P, and draw P Q parallel to N C, which will be perpendicular to A C B. The force $\frac{f}{r^2}$ in the direction P C, represented by P C, may be resolved into P N, N M, M C, that is, the resolved parts parallel to x, y, and z are $-\frac{fx}{r^3}$, $-\frac{fy}{r^3}$, $-\frac{fz}{r^3}$; where r s put for P C, and the forces are considered negative because their action tends to move the particle in such a direction as to diminish x, y, and z. The centrifugal force, if T be the time of revolution, is equal (MECHANICS, § XIV.) to $\frac{4\pi^2}{T^2}$ Q P, or $\frac{4\pi^2}{T^2}$ C N; which may be resolved into $\frac{4\pi^2}{T^2}$ C M, and $\frac{4\pi^2}{T^2}$ M N, or $\frac{4\pi^2}{T^2}x$ and $\frac{4\pi^2}{T^2}y$, in the directions of x and y. These are positive, because their action tends to increase the coordinates x and y of any particle. When the rotation is taken into account by this application of centrifugal force, we may consider the conditions of equilibrium the same as if there were no rotation. Then

$$X = -\frac{fx}{r^3} + \frac{4\pi^2}{T^2}x,$$

$$Y = -\frac{fy}{r^3} + \frac{4\pi^2}{T^2}y,$$

$$Z = -\frac{fz}{r}.$$

From which $dq = -\frac{f}{r^3}(x\,dx + y\,dy + z\,dz)$ $+ \frac{4\pi^2}{T^2}(x\,dx + y\,dy) = -\frac{f\,dr}{r^2} + \frac{2\pi^2}{T^2}d\,(x^2 + y^2)$, and $q = \frac{f}{r} + \frac{2\pi^2}{T^2}(x^2 + y^2)$. The equation to the external surface will, therefore, be

$$\frac{f}{r} + \frac{2\pi^2}{T^2}(x^2 + y^2) = C.$$

Let a be the equatorial radius; at a point in the equator $r = a$, and $x^2 + y^2 = a^2$; consequently $C = \frac{f}{a} + \frac{2\pi^2}{T^2}a^2$, and the equation is $\frac{f}{\sqrt{x^2 + y^2 + z^2}} + \frac{2\pi^2}{T^2} \times (x^2 + y^2) = \frac{f}{a} + \frac{2\pi^2}{T^2}a^2$. If the centrifugal force at

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* If the strata of homogeneous Fluid were thick, ρ would be the same where p was the same, yet p would not be the same where ρ was the same. For between the upper and lower surface of the stratum ρ would not be altered, but p would have had all values between the value at the upper and that at the lower surface.

the equator $\left(\text{or } \frac{4\pi^2}{T^2} a\right)$ be $m \times$ whole force there $\left(\text{or } m \times \left\{\frac{f}{a^2} - \frac{4\pi^2}{T^2} a\right\}\right)$, we have $\frac{4\pi^2}{T^2} = \frac{m}{1+m} \cdot \frac{f}{a^3}$; and the equation is $\frac{f}{\sqrt{x^2+y^2+z^2}} + \frac{mf}{2(1+m)a} \times (x^2+y^2) = \frac{f}{a} + \frac{mf}{2(1+m)a} = \frac{2+3m}{2+2m} \cdot \frac{f}{a}$, or

$$\frac{1}{\sqrt{x^2+y^2+z^2}} = \frac{2+3m}{2+2m} \cdot \frac{1}{a} - \frac{m}{2+2m} \cdot \frac{x^2+y^2}{a^3}.$$

The polar semiaxis, or b, will be determined by making x and $y = 0$, and $z = b$; then $\frac{1}{b} = \frac{2+3m}{2+2m} \cdot \frac{1}{a}$, or $b = \frac{2+2m}{2+3m} a$. The proportion of the diameters is, therefore, $2+3m \,.\, 2+2m$, or the flattening at the Poles is $\frac{m}{2+3m} \times$ the equatorial diameter. If these were the circumstances of the Earth, m (see MECHANICS, § XIV.) would be $\frac{1}{289}$, and the flattening would be $\frac{1}{581}$.

(13.) It must be observed that the determination of the form assumed by a revolving Fluid on the Principle of Gravitation is not so simple as the solution which we have just exhibited. In fact, one of the forces which acts on each particle (the attraction of every other particle) depends on the form; that is, one of the elements necessary to the determination of the form depends itself on the form. The extreme difficulty which this introduces will prevent us from determining, analytically, the form; and will oblige us to confine ourselves to showing, synthetically, that an elliptic surface satisfies the conditions of equilibrium. For a proof that the elliptic is the only form of equilibrium, we refer the reader to a paper by Legendre, in the *Mémoires de l'Académie*, for the year 1789.

On the Figure assumed by a Homogeneous Fluid.

(14.) We shall show that the surface formed by the revolution of an ellipse will satisfy the condition of Art. (9.) (The condition of Art. (8.), as we have explained in (10.), is already satisfied.) For this purpose we must find the attraction of a spheroid on a point at its surface.

Earth supposed homogeneous.

Attraction of a pyramid on a point in its vertex.

(15.) First it is convenient to premise the expression for the attraction of a pyramid on a point at its vertex. Let V P W, fig. 4, be a pyramid of which the base V W (to which the axis is perpendicular) is very small, its area being $= A$; call the length P V, l; then the area of the section at a distance P v (which we will call s) is $A \times \frac{s^2}{l^2}$; and if another section $v'w'$ be taken at the very small distance ds from the former, the solid content of the included frustrum is $A \cdot \frac{s^2\,ds}{l^2}$; and if k be the density of the matter, (estimated as in (5.)), the mass of the matter in the frustrum is $Ak \cdot \frac{s^2\,ds}{l^2}$. Now by the Principle of Gravitation the force of the attraction of this matter on P will be *proportional* to this quantity divided by the square of the distance, or *proportional* to $\frac{Ak}{l^2} ds$. It is *equal* to this quantity multiplied by some constant;* but as this constant must be the same in all parts of the investigation, we will omit it in every part; and consider the attraction of the matter in $v w'$ on the point P, as represented by $\frac{Ak}{l^2} ds$. The integral of this, or $\frac{Aks}{l^2} + C$, is the attraction of the pyramid; making it vanish when $s = 0$, and then making $s = l$, we have for the whole attraction $\frac{Ak}{l}$.

Spheroid divided into pyramids.

(16.) Now let C M, M N, N P, fig. 5, be the coordinates x, y, z, of a point P in the surface; let the plane A P B pass through C and N P; and refer the points of the surface to three coordinates, r, s, and z, of which r is parallel to A B, s perpendicular to A B, but in the plane A B D, and z the same as before. For the point P, therefore, r is C N, s is O, z is N P. Suppose the spheroid to be divided into wedges, (one of which is represented in fig. 6,) by planes passing through P N; let the plane P Q O make with the plane A P B an angle ϕ, and P q O an angle $\phi + d\phi$. Again suppose this wedge divided into pyramids by planes, passing through P Q q, P T t; and let Q P N or q P N be called θ; T P N or t P N, $\theta + d\theta$. Let P Q, the length of this pyramid, be l. Then the area of a section of the pyramid, perpendicular to P Q, is T $t \times t v$. But $tv = \mathrm{P}t \times d\theta = l\,d\theta$ nearly; and T t (supposing tw perpendicular to P N) is $tw \times d\phi = l \cdot \sin\theta \cdot d\phi$. The area of the section is, therefore, $l^2 \cdot \sin\theta \cdot d\phi \cdot d\theta$; and consequently, by (15.), the attraction of the pyramid is $kl \sin\theta \cdot d\phi \cdot d\theta$.

(17.) This is the attraction of the pyramid in the direction of its length. We may resolve this into two parts parallel to P N and N L: the former will be $kl \sin\theta \cdot \cos\theta \cdot d\phi \cdot d\theta$; the latter $kl \cdot \sin^2\theta\, d\phi \cdot d\theta$. This latter may be again resolved into two, one parallel to C A, and one perpendicular to it; their values are $kl \sin^2\theta \cos\phi \cdot d\phi \cdot d\theta$, and $kl \sin^2\theta \cdot \sin\phi \cdot d\phi \cdot d\theta$.

(18.) The first of these is in a direction contrary to that which tends to impress such a motion as would increase the value of z; and, therefore,

Attraction of pyramid in direction of z
$$= -kl \sin\theta \cdot \cos\theta \cdot d\phi \cdot d\theta$$

In a similar manner

Attraction of pyramid in direction of r
$$= -kl \sin^2\theta \cdot \cos\phi \cdot d\phi \cdot d\theta.$$

And

Attraction of pyramid in direction of s
$$= +kl \sin^2\theta \cdot \sin\phi \cdot d\phi \cdot d\theta.$$

The last of these we shall neglect. For when we

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* The constant would be different according as we estimated the effects of the attraction by the *pressure* which it caused by acting on a given mass at rest, or the *acceleration* which it created in its motion.

take the attraction of the whole spheroid, there will be a pyramid of equal dimensions, and in a similar position, on the opposite side of the plane A P B, whose attraction in the direction of s will have the same magnitude as this, but will have a different sign: and, consequently, they will destroy each other. If we took the attraction of a part only of the spheroid, this reasoning would not hold.

(19.) Now to get the attraction of the wedge in fig. 6, in the direction of z, we must integrate $k\,d\varphi\,.\int l\,.\,\sin\theta\,.\,\cos\theta\,.\,d\theta$. For this purpose we must express l in terms of θ and φ. Let r', s', z' be the coordinates of Q; a and b the major and minor semiaxes of the generating ellipse. Then (ANALYTICAL GEOMETRY, Art. 102.) $b^2(r'^2+s'^2)+a^2z'^2=a^2b^2$. Now $r'=r-tw\,.\cos\varphi'=r-l\sin\theta\,.\,\cos\varphi$; $s'=tw\,.\,\sin\phi=l\sin\theta\,.\,\sin\varphi$; $z'=z-\mathrm{P}w=z-l\cos\theta$. Substituting these values $b^2(r^2-2lr\sin\theta\cos\varphi+l^2\sin^2\theta)+a^2(z^2-2lz\cos\theta+l^2\cos^2\theta)=a^2b^2$. But as P is a point in the surface, and s there is 0, $b^2r^2+a^2z^2=a^2b^2$. Subtracting this equation from the former, $b^2l^2\sin^2\theta+a^2l^2\cos^2\theta-2b^2lr\sin\theta\cos\varphi-2a^2lz\cos\theta=0$; whence

$$l=\frac{2b^2r\sin\theta\cos\varphi+2a^2z\cos\theta}{b^2\sin^2\theta+a^2\cos^2\theta}.$$

All the integrations must be performed between the values $\theta=0$, and $\theta=$ that value which makes $l=0$; that is from $\theta=0$, to $\theta=$ the arc whose tangent is $\dfrac{-a^2z}{b^2r\cos\phi}$.

(20.) The attraction of the wedge, therefore, in the direction of z

$$=\quad k\,d\varphi\int\frac{2b^2r\sin\theta\cos\varphi+2a^2z\cos\theta}{b^2\sin^2\theta+a^2\cos^2\theta}\sin\theta\,.\cos\theta\,.d\theta$$

$$=d\varphi\int\left\{\frac{-2b^2r\cos\varphi.\sin^2\theta\,.\cos\theta\,.d\theta}{b^2\sin^2\theta+a^2\cos^2\theta}-\frac{2a^2z\cos^2\theta\,.\sin\theta\,.d\theta}{b^2\sin^2\theta+a^2\cos^2\theta}\right\}$$

Making $b^2=a^2(1-e^2)$, the general integral is

$$kr\cos\phi\,.\,d\phi\left\{\frac{1-e^2}{e^2}\sin\theta-\frac{1-e^2}{e^3}\log\sqrt{\frac{1+e\sin\theta}{1-e\sin\theta}}\right\}$$

$$+2kz\,d\phi\left\{\frac{1}{e^2}\cos\theta-\frac{\sqrt{1-e^2}}{e^3}\tan^{-1*}\left(\frac{e}{\sqrt{1-e^2}}\cos\theta\right)\right\}.$$

Taking this from $\theta=0$ to $\theta=\tan^{-1}\left(\dfrac{-a^2z}{b^2r\cos\varphi}\right)=\sin^{-1}\left(\dfrac{-a^2z}{\sqrt{a^4z^2+b^4r^2\cos^2\varphi}}\right)=\cos^{-1}\left(\dfrac{b^2r\cos\varphi}{\sqrt{a^4z^2+b^4r^2\cos^2\varphi}}\right)$,

we have the attraction of the wedge

$$=2kr\cos\varphi\,d\varphi\left\{-\frac{1-e^2}{e^2}\,.\,\frac{a^2z}{\sqrt{a^4z^2+b^4r^2\cos^2\varphi}}-\frac{1-e^2}{e^3}\log\frac{\sqrt{a^4z^2+b^4r^2\cos^2\varphi}-a^2ez}{\sqrt{a^4z^2+b^4r^2\cos^2\varphi}+a^2ez}\right\}$$

$$+2kz\,d\varphi\left\{\frac{b^2r\cos\varphi}{e^2\sqrt{a^4z^2+b^4r^2\cos^2\varphi}}-\frac{\sqrt{1-e^2}}{e^3}\tan^{-1}\frac{b^2er\cos\varphi}{\sqrt{1-e^2}\,\sqrt{a^4z^2+b^4r^2\cos^2\varphi}}-\frac{1}{e^2}+\frac{\sqrt{1-e^2}}{e^3}\tan^{-1}\frac{e}{\sqrt{1-e^2}}\right\}.$$

Now it may be observed, that all the terms, except the two last, are of such a nature, that upon increasing φ by a semi-circumference, or π, their value is the same but the sign is different, and the addition of two such expressions, one corresponding to the arc φ, and the other to the arc $\pi+\varphi$, will therefore destroy both. As we shall shortly integrate with respect to φ, from $\varphi=0$ to $\varphi=2\pi$, we shall in reality effect that addition. We may as well then reject, at once, these useless terms; and thus we find for the effective attraction of the wedge in the direction of z,

$$2kz\,d\varphi\left(-\frac{1}{e^2}+\frac{\sqrt{1-e^2}}{e^3}\tan^{-1}\frac{e}{\sqrt{1-e^2}}\right)\text{ or }2z\,d\varphi\left(\frac{\sqrt{1-e^2}}{e^3}\sin^{-1}e-\frac{1}{e^2}\right).$$

(21.) To find the attraction of the whole spheroid in the direction of z, we must integrate this with respect to φ, from $\varphi=0$ to $\varphi=2\pi$, and we get $4\pi k\left(\dfrac{\sqrt{1-e^2}}{e^3}\sin^{-1}e-\dfrac{1}{e^2}\right).\ z$.

(22.) The attraction of the wedge in the direction of r is

$$k\cos\varphi\,d\varphi\int\left\{\frac{-2b^2r\cos\varphi\,.\,\sin^3\theta\,.\,d\theta}{b^2\sin^2\theta+a^2\cos^2\theta}-\frac{2a^2z\sin^2\theta\,.\cos\theta\,.\,d\theta}{b^2\sin^2\theta+a^2\cos^2\theta}\right\}.$$

The general integral is

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[*] We use the expression $\tan^{-1}\left(\dfrac{e}{\sqrt{1-e^2}}\cos\theta\right)$ to denote the arc whose tangent is $\dfrac{e}{\sqrt{1-e^2}}\cos\theta$; and, similarly, for other functions.

$$2kr\cos^2\phi\, d\phi\left\{-\frac{1-e^2}{e^2}\cos\theta+\frac{\sqrt{1-e^2}}{e^3}\,.\tan^{-1}\frac{e\cos\theta}{\sqrt{1-e^2}}\right\}$$

$$+\,2kz\cos\phi\, d\varphi\left\{\frac{1}{e}\sin\theta-\frac{1}{e^3}\log\sqrt{\frac{1+e\sin\theta}{1-e\sin\theta}}\right\}.$$

On taking this between the limits $\theta = 0$, $\theta = \tan^{-1}\,.\,\frac{-a^2 z}{b^2 r\cos\varphi}$, and rejecting (as in (20.)) those terms which ultimately produce no effect, we have for the effective attraction of the wedge in the direction of r

$$2kr\cos^2\varphi\,.\,d\varphi\left\{\frac{1-e^2}{e^2}-\frac{\sqrt{1-e^2}}{e^3}\sin^{-1}e\right\}.$$

(23.) To find the attraction of the whole spheroid in the direction of r we must integrate this with respect to φ from $\varphi = 0$ to $\varphi = 2\pi$: we thus get $2\pi k\left(\frac{1-e^2}{e^2}-\frac{\sqrt{1-e^2}}{e^3}\sin^{-1}e\right).\,r$.

(24.) Besides these forces of attraction there is the centrifugal force, which (as in (12.)) is $\frac{4\pi^2}{T^2}r$ in the direction of r. The whole force, therefore, in the direction of r is $2\pi k\left(\frac{1-e^2}{e^2}-\frac{\sqrt{1-e^2}}{e^3}\sin^{-1}e+\frac{2\pi}{T^2k}\right)r$.

(25.) Resolving the force in the direction of r or C N, fig 5, into two in the directions of C M and M N, or x and y, we find that they are the same multiples of x and y which the force in the direction of r is of r. Thus we have the following expressions:

Expressions for the forces on a particle at the surface of the spheroid.

$$X = 2\pi k\left(\frac{1-e^2}{e^2}-\frac{\sqrt{1-e^2}}{e^3}\sin^{-1}e+\frac{2\pi}{T^2k}\right)x = 2\pi\,.\,k\mathrm{A}\,.\,x.$$

$$Y = 2\pi k\left(\frac{1-e^2}{e^2}-\frac{\sqrt{1-e^2}}{e^3}\sin^{-1}e+\frac{2\pi}{T^2k}\right)y = 2\pi k\mathrm{A}\,.\,y.$$

$$Z = 4\pi k\left(\frac{\sqrt{1-e^2}}{e^3}\sin^{-1}e-\frac{1}{e^2}\right)z = 4\pi\,.\,k\,.\,\mathrm{B}z.$$

The elliptic form proper for equilibrium.

(26.) The condition in (8.) now requires that the external surface be defined by the equation $X\,dx + Y\,dy + Z\,dz = 0$, or $2\pi k\mathrm{A}x\,dx + 2\pi k\mathrm{A}y\,dy + 4\pi k\mathrm{B}z\,dz = 0$, or (integrating and dividing by πk) $\mathrm{A}(x^2+y^2) + 2\mathrm{B}z^2 = \mathrm{C}$. But the equation to the surface has already been assumed to be $b^2(x^2+y^2)+a^2z^2 = a^2b^2$. (Analytical Geometry, Art. 102.) If these equations are compatible, the elliptic form is proper for equilibrium, and a comparison of the constants will determine the degree of ellipticity. Now the form of the equations is precisely the same, and, therefore, they will be compatible if the proportion of the coefficients of x^2+y^2 and z^2 is the same (C being undetermined.) This condition requires that $\frac{\mathrm{A}}{2\mathrm{B}} = \frac{b^2}{a^2} = 1-e^2$, or $\mathrm{A} - 2\mathrm{B}(1-e^2) = 0$, or

$$\frac{3(1-e^2)}{e^2}-\frac{3-2e^2}{e^2}\sqrt{1-e^2}\,.\,\sin^{-1}e+\frac{2\pi}{T^2k}=0,$$

Equation for finding the ellipticity.

an equation from which, when T^2k is known, e can be found.

(27.) If $\sin^{-1}e = f$, the equation may be put under this form, (which is more convenient for calculation,)

$$f\,.\cot f(1+3\cot^2 f)-3\cot^2 f-\frac{2\pi}{T^2k}=0.$$

If a curve be constructed of which the abscissa is f, and the ordinate the equation deprived of its last term, it will be found to resemble A E F B, fig. 7. If we draw a straight line, C D, parallel to A B, and at a perpendicular distance equal to $\frac{2\pi}{T^2k}$, the points in which it cuts the curve will have for abscissæ the values of f, which satisfy the equation. From this it appears that if $\frac{2\pi}{T^2k}$ does not exceed a certain limit (.22467), there are two values of f and, consequently, of e, or two forms of ellipsoid, with which equilibrium is possible; if it exceed that limit, equilibrium is not possible.

(28.) We have spoken here as if the velocity of rotation was independent of the form of the spheroid. This would not be the case, if in consequence of want of adaptation of the forces the form of the Fluid should change. Nothing, therefore, can be inferred with regard to the stability of the equilibrium. To investigate this we must make use of the following theorem of Mechanics, (known as *the principle of the conservation of areas*) If any bodies revolve round a centre, and are acted on only by their mutual attraction and by forces directed to the centre, the sum of the products of the mass of each by the projection (on a given plane) of the area which it describes round that centre is constant. In the case before us the particles of the Fluid are acted on only by their mutual attraction, and therefore this theorem applies. Now (without making a complete investigation) it is easily seen that the sum of the products of the mass by the area described does not depend on the length of the axis of revolution, but is proportional to the square of the major axis directly, and the time of revolution inversely. That is, $C' = \frac{a^2}{T}$, or $T = \frac{a^2}{C'}$. And since the quantity of matter is given, $C'' = a^2 b = a^3 \sqrt{1-e^2}$; whence $a^3 = \frac{C''}{\overline{1-e^2}|^{\frac{1}{2}}}$.

$a = \frac{C''^{\frac{2}{3}}}{\overline{1-e^2}|^{\frac{1}{3}}}$; and $T = \frac{C''^{\frac{2}{3}}}{C'.\overline{1-e^2}|^{\frac{1}{3}}}$; $\frac{2\pi}{T^2} = \frac{2\pi . C'^2}{C''^{\frac{4}{3}}} \overline{1-e^2}|^{\frac{2}{3}} = D . \overline{1-e^2}|^{\frac{2}{3}}$ for abbreviation. Substituting this in the equation of (27.), and putting $\overline{\cos f}|^{\frac{4}{3}}$ for $\overline{1-e^2}|^{\frac{2}{3}}$, we have

$$f . \cot f . (1 + 3 \cot^2 f) - 3 \cot^2 f - \frac{D}{k} \overline{\cos f}|^{\frac{4}{3}} = 0,$$

$$\text{or } \frac{1}{\overline{\cos f}|^{\frac{4}{3}}} \{ f \cot f . (1 + 3 \cot^2 f) - 3 \cot^2 f \} - \frac{D}{k} = 0.$$

A given mass, in motion, with a given velocity, has only one form of equilibrium. The equilibrium is stable.

If we construct a curve of which f is the abscissa, and this expression deprived of its last term the ordinate, it will be found to resemble fig. 8, the ordinate becoming infinite when $f = 90°$, or $e = 1$. And, therefore, if we draw C D parallel to A B at the distance $\frac{D}{k}$, it will cut the curve at one point and at no more. It appears, then, that the equation above admits in all cases of one solution and of no more than one; and, consequently, if a fluid mass is revolving round an axis, there is always one elliptic spheroid, and only one, in which it can remain in equilibrium. It will very easily be seen that if it be put in the form of a less flattened spheroid, its angular velocity must be increased, and therefore it will return to the form of the spheroid of equilibrium; if it be made too flat, the angular velocity will be diminished and it will also return to that form. Hence the equilibrium is always stable. We have given this proposition, perhaps, more attention than it deserves, because the preceding proposition has sometimes been stated in such a form as to imply that a mass of Fluid might have two forms of equilibrium, and might have one form of unstable equilibrium; conclusions which are quite incorrect.

(29.) With regard to the Earth considered as a homogeneous Fluid, we do not immediately know k, but we know the force of Gravity at the Equator, and we can calculate the centrifugal force there, and, consequently, know their ratio; let this be m. The whole Gravity at the Equator, by (23.), making $r = a$, and changing the sign, is $2\pi k . \left(-\frac{1-e^2}{e^2} + \frac{\sqrt{1-e^2}}{e^3} \sin^{-1} e - \frac{2\pi}{T^2 k} \right) . a$; the centrifugal force is $2\pi k . \frac{2\pi}{T^2 k} a$;

$$\text{hence } \frac{2\pi}{T^2 k} = m \left(\frac{\sqrt{1-e^2}}{e^3} \sin^{-1} e - \frac{1-e^2}{e^2} - \frac{2\pi}{T^2 k} \right), \text{ and } \frac{2\pi}{T^2 k} = \frac{m}{1+m} \left(\frac{\sqrt{1-e^2}}{e^3} \sin^{-1} e - \frac{1-e^2}{e^2} \right)$$

$$= \frac{m}{1+m} \left(\frac{f . \cos f}{\sin^3 f} - \cot^2 f \right).$$

The equation of (27.) is changed by this substitution into the following:

$$\frac{f \cot f (1 + 3 \cot^2 f) - 3 \cot^2 f}{f \cot f (1 + \cot^2 f) - \cot^2 f} - \frac{m}{1+m} = 0.$$

If we construct a curve whose abscissa is f, and ordinate the first term of this equation, it will have the form of fig. 9, the ordinate being $= 1$ when $f = 90°$. If the line C D be drawn parallel to A B, and at the distance $\frac{m}{1+m}$, since $\frac{m}{1+m}$ is less than 1, it will necessarily cut this curve at some point E, and only at one point.

Only one form corresponding to a given ratio of centrifugal force to Gravity.

One corresponding value of f, and consequently one of e, and no more than one, may therefore be found for any given value of m; that is, the ratio of the centrifugal force at the Equator to Gravity there being known, there is but one elliptic form, which will be a form of equilibrium.

Approximate solution of the equation.

(30.) Where m is so small as in the case of the Earth $\left(\frac{1}{289}\right)$, we may be satisfied with a first approximation. Let $a = b(1 + \epsilon)$: ϵ is what is generally called the ellipticity. Then l in (19.) is

$$\frac{2 r \sin\theta . \cos\varphi + 2 z (1 + \epsilon)^2 \cos\theta}{\sin^2\theta + (1 + \epsilon)^2 \cos^2\theta};$$

and if we neglect the square of ϵ, this is

$$\frac{2 r \sin\theta . \cos\varphi + 2 z \cos\theta + 4 \epsilon . z \cos\theta}{1 + 2 \epsilon \cos^2\theta} = 2 r \sin\theta . \cos\varphi + 2 z \cos\theta + \epsilon (4 z \sin^2\theta \cos\theta - 4 r \sin\theta . \cos^2\theta \cos\varphi),$$

gure of e Earth.

Physical Theory. Earth supposed homogeneous.

The attraction of the wedge in the direction of z is, therefore,

$$-k d\phi \int \{ 2r\cos\phi . \sin^2\theta . \cos\theta . d\theta + 2z\cos^2\theta . \sin\theta . d\theta + \epsilon\,(4z . \sin^3\theta . \cos^2\theta . d\theta - 4r\cos\phi . \sin^2\theta\cos^3\theta\, d\theta) \} .$$

The general integral is

$$-k\,d\phi \left\{ \frac{2}{3} r\cos\phi . \sin^3\theta - \frac{2}{3} z\cos^3\theta + \epsilon \left(4z . \overline{\frac{\cos^5\theta}{5} - \frac{\cos^3\theta}{3}} - 4r\cos\phi . \overline{\frac{\sin^3\theta}{3} - \frac{\sin^5\theta}{5}} \right) \right\};$$

taking this between the same limits as in (20.), and selecting in the same way the effective terms, we find the effective attraction of the wedge $= -k\,d\phi \left\{ \frac{2}{3} z + \frac{8}{15}\epsilon z \right\}$. Integrating this from $\phi = 0$ to $\phi = 2\pi$, we have for the attraction of the spheroid in the direction of z,

$$-2\pi k \left\{ \frac{2}{3} z + \frac{8}{15}\epsilon z \right\} = -\frac{4\pi}{3} k \left(1 + \frac{4}{5}\epsilon\right) z.$$

(31.) The attraction of the wedge in the direction of r is

$$-k\cos\phi . d\phi \int \{ 2r\cos\phi\sin^3\theta . d\theta + 2z\sin^2\theta . \cos\theta . d\theta + \epsilon\,(4z\sin^4\theta\cos\theta\, d\theta - 4r\cos\phi\sin^3\theta\cos^2\theta . d\theta) \}$$

The general integral is

$$-k\cos\phi . d\phi \left\{ 2r\cos\phi \times \overline{\frac{\cos^3\theta}{3} - \cos\theta} + 2z\frac{\sin^3\theta}{3} + \epsilon \left(4z\frac{\sin^5\theta}{5} - 4r\cos\phi . \overline{\frac{\cos^5\theta}{5} - \frac{\cos^3\theta}{3}} \right) \right\}$$

The effective part found in the same manner is

$$-k\cos\phi . d\phi \left\{ \frac{4}{3} r\cos\phi - \frac{8}{15}\epsilon r\cos\phi \right\}.$$

Integrating this from $\phi = 0$ to $\phi = 2\pi$, the attraction of the spheroid in the direction of r is

$$-\pi k \left\{ \frac{4}{3} r - \frac{8}{15}\epsilon r \right\} = -\frac{4\pi}{3} k \left(1 - \frac{2}{5}\epsilon\right) . r.$$

Expressions for the attraction of a point in the surface when the ellipticity is small.

(32.) Applying the centrifugal force $= \frac{4\pi^2}{T^2} r$, and resolving the force in the direction of r into two in the direction of x and y, we get the following expressions,

$$X = -\frac{4\pi}{3} k \left(1 - \frac{2}{5}\epsilon - \frac{3\pi}{kT^2}\right) x.$$

$$Y = -\frac{4\pi}{3} k \left(1 - \frac{2}{5}\epsilon - \frac{3\pi}{kT^2}\right) y.$$

$$Z = -\frac{4\pi}{3} k \left(1 + \frac{4}{5}\epsilon\right) z.$$

The equation to the external surface must, therefore, be $\left(\text{omitting } -\frac{4\pi}{B} k\right)$

$$\left(1 - \frac{2}{5}\epsilon - \frac{3\pi}{kT^2}\right)(x^2 + y^2) + \left(1 + \frac{4}{5}\epsilon\right) z^2 = C.$$

But it has been assumed to be $b^2(x^2 + y^2) + b^2 . (1 + 2\epsilon) . z^2 = b^4(1 + 2\epsilon)$. Making the proportion of the coefficients of $x^2 + y^2$ and z^2 the same,

$$1 + 2\epsilon = \frac{1 + \frac{4}{5}\epsilon}{1 - \frac{2}{5}\epsilon - \frac{3\pi}{kT^2}}, \text{ or } 1 + \frac{8}{5}\epsilon - \frac{3\pi}{kT^2} = 1 + \frac{4}{5}\epsilon; \text{ whence } \epsilon = \frac{15\pi}{kT^2}.$$

(33.) Using m to signify the same thing as in (29.), $m = \dfrac{\frac{4\pi^2}{T^2}(1 + \epsilon)}{\frac{4\pi}{3} k \left(1 - \frac{2}{5}\epsilon\right)(1 + \epsilon)\, b} = \dfrac{12\pi}{kT^2}$ nearly; whence $\frac{\pi}{kT^2} = \frac{m}{12}$, and $\epsilon = \frac{5}{4} m$. If the Earth were a homogeneous fluid, m being $\frac{1}{289}$, ϵ would be $\frac{5}{4} \times \frac{1}{289} = \frac{1}{230}$: and the ratio of the axes would be $1 : 1 + \epsilon$ or $230 : 231$.

Expression for Gravity.

(34.) We have nothing remaining but to investigate the magnitude of Gravity (including the effects of attraction and centrifugal force) at any point of the surface. Since the forces X, Y, Z are at right angles to each other, the force compounded of them all is $\sqrt{X^2 + Y^2 + Z^2}$, (MECHANICS, § VI.) which, taking the expressions in (25.) $= 2\pi k\sqrt{A^2(x^2 + y^2) + 4B^2 z^2}$. But by (26.) $\frac{A}{2B} = \frac{b^2}{a^2}$: whence the force

$= 2\pi k\sqrt{\frac{b^4}{a^4}4B^2(x^2+y^2)+4B^2z^2} = 4\pi k B\sqrt{\frac{b^4}{a^4}r^2+z^2}$. Let fig. 10 represent the section of the spheroid through the point P and the axis; draw PR the normal at P. Then (Conic Sections, Art. 34.) $RN = \frac{b^2}{a^2}CN = \frac{b^2}{-}r$; and $PN = z$; therefore $PR = \sqrt{\frac{b^4}{a^4}r^2+z^2}$, and, consequently, the force is proportional to PR.

Gravity expressed in terms of the latitude.

(35.) An expression in terms of the angle PRN (or the latitude of P) may be thus obtained. Let $PRN = \lambda$; $PR = n$; PN or $z = n\sin\lambda$; CN or $r = \frac{a^2}{b^2}RN = \frac{a^2}{b^2}n\cos\lambda$; and substituting these in the equation to the ellipse, $r^2b^2+a^2z^2 = a^2b^2$, it becomes $n^2\left(\frac{a^4}{b^2}\cos^2\lambda + a^2\sin^2\lambda\right) = a^2b^2$, whence $n = \frac{b^2}{\sqrt{a^2\cos^2\lambda + b^2\sin^2\lambda}}$. If $a = b(1+\epsilon)$ and powers of ϵ higher than the first be neglected, this becomes $n = \frac{b}{\sqrt{1+2e\cos^2\lambda}} = b(1-\epsilon\cos^2\lambda) = b\,.\,\overline{1-\epsilon}\,.\,(1+\epsilon\sin^2\lambda)$: and the force is, therefore, proportional to $1+\epsilon\sin^2\lambda$, or $1+\frac{5}{4}m\,.\,\sin^2\lambda$.

On the Figure assumed by a Heterogeneous Fluid.

(36.) The difficulties attending this investigation are so considerable that it would be useless to attempt a complete solution. We shall confine ourselves to an approximation including all terms depending on the first powers of the ellipticities: the reader who may desire to see an approximation including the terms depending on the squares of the ellipticities, and obtained by a different method, is referred to the *Phil. Trans.* for the year 1826.

Method of proceeding in the investigation for a heterogeneous Fluid.

(37.) We shall assume that the form of each homogeneous stratum is elliptical, and that the ellipticity is different for the different strata; so that if we consider the extent of any homogeneous stratum to be sensible, it will be bounded by surfaces of different ellipticities. We shall then investigate the forces produced by each stratum, and by the whole, upon a point in any position: adding the centrifugal force, we shall form the expressions for X, Y, Z; and as we know (Art. 9.) that $X\,dx + Y\,dy + Z\,dz$ is a complete differential, we shall only assume that $X\,dx + Y\,dy + Z\,dz = 0$ is the equation to the surface limiting every homogeneous stratum. We shall then show that this equation agrees with that assumed in the first instance, provided a certain condition be satisfied; from which we shall infer at once the most important deductions relating to the Figure of the Earth.

(38.) Our first object then must be, to investigate the attraction of a shell, bounded by two spheroidal surfaces of different ellipticities, on a point within it or without it. As this is the same as the difference of attractions of two spheroids whose axes and ellipticities are different, we shall begin with investigating the attraction of a spheroid; and first on a point within it.

(39.) It is convenient to premise, that if two pyramids of different lengths have equal solid angles, (that is, if heir sections at a given distance from the vertex be equal,) their attractions are proportional to their lengths. For the attraction of one such pyramid (15.) is $\frac{A\,k}{l}$; that of another $\frac{A'\,k}{l'}$; their proportion is $\frac{A\,l'}{A'\,l}$; but if their solid angles be equal, $\frac{A}{A'} = \frac{l^2}{l'^2}$; therefore the proportion of the attractions is $\frac{l}{l'}$.

Attraction of a homogeneous spheroid on a point within it.

(40.) Now let fig. 11 be constructed in the same manner as fig. 5, except that P, instead of being at the surface of the spheroid, is in the interior; and produce the planes which are the sides of the pyramid QP to meet the other surface about the point Q. The attraction of the pyramids PQ, PQ′, are in opposite directions, and proportional to their lengths, and, consequently, their combined attraction is that of a pyramid whose length is PQ − PQ′, and whose solid angle is the same. Now, using the same notation as in (19.), and forming the same equation, we have

$$l^2(b^2\sin^2\theta + a^2\cos^2\theta) - 2l(a^2z\cos\theta + b^2r\sin\theta\,.\cos\phi) = a^2b^2 - a^2z^2 - b^2r^2;$$

whence

$$l = \frac{a^2z\cos\theta + b^2r\sin\theta\cos\phi}{b^2\sin^2\theta + a^2\cos^2\theta} \pm \frac{1}{b^2\sin^2\theta + a^2\cos^2\theta}\sqrt{\{(a^2b^2 - a^2z^2 - b^2r^2)(b^2\sin^2\theta + a^2\cos^2\theta) + (a^2z\cos\theta + b^2r\sin\theta\cos\phi)^2\}}$$

$$= \frac{a^2z\cos\theta + b^2r\sin\theta\cos\phi}{b^2\sin^2\theta + a^2\cos^2\theta} \pm \sqrt{R}\text{ suppose.}$$

One of these roots represents PQ; the other represents PQ′ estimated in the direction of PQ, that is, if its sign be changed it represents the length of PQ′. Thus

$$PQ = \sqrt{R} + \frac{a^2z\cos\theta + b^2r\sin\theta\cos\phi}{b^2\sin^2\theta + a^2\cos^2\theta},$$

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$$PQ' = \sqrt{R} - \frac{a^2 z \cos\theta + b^2 r \sin\theta . \cos\varphi}{b^2 \sin^2\theta + a^2 \cos^2\theta},$$

whence

$$PQ - PQ' = \frac{2\, a^2 z \cos\theta + 2\, b^2 r \sin\theta \cos\varphi}{b^2 \sin^2\theta + a^2 \cos^2\theta}$$

These two pyramids are now to be treated as if they were a single pyramid of length $PQ - PQ'$; and hence we shall have (calling the density ρ)

$$\text{force in direction of } z = -\rho\, (PQ - PQ') \sin\theta . \cos\theta . d\varphi . d\theta,$$

$$\text{force in direction of } r = -\rho\, (PQ - PQ') \sin^2\theta . \cos\varphi . d\varphi . d\theta.$$

The force in the direction of s may be neglected as before.

(41.) Let $a = b\,(1 + e)$; and neglect e^2, e^3, &c. Then

$$PQ - PQ' = 2\, r \cos\varphi \sin\theta + 2\, z \cos\theta + e\, (4\, z \sin^2\theta \cos\theta - 4\, r \cos\varphi . \sin\theta . \cos^2\theta).$$

The force in the direction of z

$$= -\rho\, d\varphi \left\{ 2 r \cos\varphi . \sin^2\theta . \cos\theta . d\theta + 2 z \cos^2\theta . \sin\theta\, d\theta + e\, (4 z \sin^3\theta . \cos^2\theta . d\theta - 4 r . \cos\varphi \sin^2\theta . \cos^3\theta . d\theta \right\}.$$

Integrating this from $\theta = 0$ to $\theta = \pi$, we have for the attraction of the whole double wedge $LQOQ'L$,

$$-\rho\, d\varphi \left\{ \frac{4\, z}{3} + \frac{16}{15} e z \right\}.$$

Integrating this from $\varphi = 0$ to $\varphi = \pi$, we have, attraction of whole spheroid in the direction of z

$$= -\frac{4\pi}{3} \rho \left(1 + \frac{4}{5} e\right) z.$$

(42.) For the force in the direction of r we must in the same way integrate

$$-\rho \cos\varphi . d\varphi . \left\{ 2 r \cos\varphi . \sin^3\theta\, d\theta + 2 z \sin^2\theta . \cos\theta\, d\theta + e\, (4 z \sin^4\theta . \cos\theta\, d\theta - 4 r \cos\varphi . \sin^3\theta . \cos^2\theta . d\theta) \right\},$$

and we find that the attraction of the whole spheroid in the direction of r

$$= -\frac{4\pi}{3} \rho \left(1 - \frac{2}{5} e\right) r.$$

These expressions are independent of the dimensions of the spheroid, provided that it contain the point, and that the ellipticity have the given value e. If, then, two spheroidal surfaces of equal ellipticity but of different dimensions surround the point, the attraction of the matter included between them, upon that point, is nothing. But this will not apply to our present purpose.

Attraction of a homogeneous spheroidal shell on a point within it.

(43.) Now let the spheroid in fig. 11 be surrounded by another spheroid indefinitely near, and of which the ellipticity is $e + de$. Then if the matter whose density is ρ extend to the first spheroid, its attraction on P in the direction of z is $-\frac{4\pi}{3} \rho z - \frac{16\pi}{15} \rho e z$. If it extend to the second spheroid, its attraction is $-\frac{4\pi}{3} \rho z - \frac{16\pi}{15} \rho e z - \frac{16\pi}{15} \rho z . de$. The difference, or the attraction of the stratum included between them, is $-\frac{16\pi}{15} z \rho\, de$. In the same manner, the attraction of the same stratum in the direction of $r = \frac{\quad}{15} r . \rho\, de$.

Attraction of a series of spheroidal shells of different densities on a point within them.

(44.) Now, if we suppose a great number of such thin strata to rest one upon another, as in fig. 12, it will be evident that their attraction in the directions of z and r is to be found by integrating the expressions in the last article. As ρ and e will both be known from a knowledge of the polar semiaxis of the spheroid to which they belong, that is as ρ and e are functions of b, we can put the attractions in this form:

$$\text{Attraction of assemblage of strata in direction of } z = -\frac{16\pi}{15} z \int \rho \frac{de}{db} . db.$$

$$\text{Attraction in direction of } r = \frac{8\pi}{15} r \int \rho \frac{de}{db} . db.$$

The function $\int \rho \frac{de}{db} db$ we shall denote by $\chi(b)$; and if b' be the axis of the inner stratum (which, however, must include or contain P), and b'' that of the exterior stratum, the value of the integral $\int \rho \frac{de}{db} db$ in the present instance will be $\chi(b'') - \chi(b')$; and then the attractions of the assemblage of strata in the directions of z and r are respectively $-\frac{16\pi}{15} z\, (\chi(b'') - \chi(b'))$, and $\frac{8\pi}{15} r\, (\chi(b'') - \chi(b'))$.

(45.) The attraction of a spheroid on a point without it is not found so directly. It will be shown to bear a known proportion to the attraction of another spheroid on a point in a different situation within it; from which, with the assistance of the expressions obtained in (41.) and (42.), its value can be found. For this purpose we must investigate the attraction of a small prism in the direction of its length on a point without it. Let A B

Attraction of a prism on a point without it.

fig. 13, be a prism, the area of whose section is very small and $= \text{A}$; upon the axis produced draw P C, a perpendicular; let $\text{CA} = a$, $\text{CB} = b$, $\text{PC} = c$, $\text{CQ} = x$; at the distances x and $x + dx$, let sections be made; the solid content intercepted is $\text{A} . dx$; and if ρ be the density, the quantity of matter is $\rho . \text{A} . dx$; the distance from P is $\sqrt{c^2 + x^2}$, and therefore the attraction is $\frac{\rho . \text{A} . dx}{c^2 + x^2}$ in the direction PQ, the resolved part of this in the direction C Q is $\frac{\rho . \text{A} . dx}{c^2 + x^2} \times \frac{x}{\sqrt{c^2 + x^2}} = \rho . \text{A} . \frac{x\,dx}{(c^2 + x^2)^{\frac{3}{2}}}$; by integration we get the attraction of the prism $= \text{constant} - \frac{\rho . \text{A} .}{\sqrt{c^2 + x^2}}$; and taking this between the limits $x = a$, $x = b$, it is

$$\rho . \text{A} . \left(\frac{1}{\sqrt{c^2 + a^2}} \frac{1}{\sqrt{c^2 + b^2}}\right) = \rho . \text{A} . \left(\frac{1}{\text{PA}} - \frac{1}{\text{PB}}\right)$$

(46.) Now, in fig. 14, let A B be an ellipsoid, of which the three semiaxes are a, b, c; and let the coordinates of the point P be r, s, z. Parallel to the axis of b and c take two sections whose distances from C are f and $f + df$; and divide the included space into prisms by sections parallel to the axes of a and c, of which two are at the distances g and $g + dg$ from C B; let TT′, the length of that prism, be $2h$. Then the area of its section is $df . dg$; also $\text{PT} = \sqrt{\overline{r-f}|^2 + \overline{s-g}|^2 + \overline{z-h}|^2}$, and $\text{PT}' = \sqrt{\overline{r-f}|^2 + \overline{s-g}|^2 + \overline{z+h}|^2}$, whence (by the last article) the attraction of the prism on P in the direction P N′ is

$$\rho . df . dg \left\{\frac{1}{\sqrt{\overline{r-f}|^2 + \overline{s-g}|^2 + \overline{z-h}|^2}} - \frac{1}{\sqrt{\overline{r-f}|^2 + \overline{s-g}|^2 + \overline{z+h}|^2}}\right\}.$$

This is to be integrated, first with respect to g from $g = -\text{RV}$ to $g = \text{RW}$, which will give the attraction of the slice, and then with respect to f from $f = -a$ to $f = +a$, which will give the attraction of the whole ellipsoid on P in the direction PN′.

Expression to be integrated for the attraction of a homogeneous spheroid on a point without it.

(47.) Let $f = ma$, $g = nb$, $h = pc$. The general equation to the ellipsoid is $\frac{f^2}{a^2} + \frac{g^2}{b^2} + \frac{h^2}{c^2} = 1$, or $m^2 + n^2 + p^2 = 1$; and at the points V and W, $h = 0$, and $\frac{f^2}{a^2} + \frac{g^2}{b^2} = 1$, or $m^2 + n^2 = 1$, whence the extreme values of n are $\pm \sqrt{1 - m^2}$. Also $df = a\,dm$, $dg = b\,dn$. Hence the attraction of the ellipsoid is

$$\rho a b \int dm \int dn \left\{\frac{1}{\sqrt{\overline{r-ma}|^2 + \overline{s-nb}|^2 + \overline{z-pc}|^2}} - \frac{1}{\sqrt{\overline{r-ma}|^2 + \overline{s-nb}|^2 + \overline{z+pc}|^2}}\right\},$$

where the first integration is to be made from $n = -\sqrt{1 - m^2}$ to $n = +\sqrt{1 - m^2}$, and the second from $m = -1$ to $m = +1$.

(48.) In the same manner the attraction of an ellipsoid whose semiaxes are a', b', c' in the same direction on a point whose coordinates are r', s', z', is

$$\rho . a' . b' . \int dm \int dn \left\{\frac{1}{\sqrt{\overline{r'-ma'}|^2 + \overline{s'-nb'}|^2 + \overline{z'-pc'}|^2}} - \frac{1}{\sqrt{\overline{r'-ma'}|^2 + \overline{sn-b'}|^2 + \overline{z+pc'}|^2}}\right\},$$

where the integrals are to be taken between the same limits as before.

(49.) Now the terms within the brackets will be precisely equal in the two expressions, if the following equations hold,

$$a'r' = ar, \quad \text{or} \quad \frac{r'}{a} = \frac{r}{a'} : \text{ let this } = \mu.$$

$$b's' = bs, \quad \text{or} \quad \frac{s'}{b} = \frac{s}{b'} \qquad = \nu.$$

$$c'z' = cz, \quad \text{or} \quad \frac{z'}{c} = \frac{z}{c'} \qquad = \pi.$$

Relation between the attraction of a spheroid on a point without it, and the attraction of another spheroid on a point within it.

Also, $m^2 a'^2 + n^2 b'^2 + p^2 c'^2 + r'^2 + s'^2 + z'^2 = m^2 a^2 + n^2 b^2 + p^2 c^2 + r^2 + s^2 + z^2$; which equation, putting $1 - m^2 - n^2$ for p^2 and $\alpha - \mu^2 - \nu^2$ for π^2, will become

$$c'^2 + m^2 (a'^2 - c'^2) + n^2 (b'^2 - c'^2) + \alpha c^2 + \mu^2 (a^2 - c^2) + \nu^2 (b^2 - c^2)$$
$$= c^2 + m^2 (a^2 - c^2) + n^2 (b^2 - c^2) + \alpha c'^2 + \mu^2 (a'^2 - c'^2) + \nu^2 (b'^2 - c'^2).$$

And as m and n are variable, this can only be satisfied by taking

$$a^2 - c^2 = a'^2 - c'^2$$
$$b^2 - c^2 = b'^2 - c'^2$$
$$\alpha = 1."$$

The last gives $\mu^2 + \nu^2 + \pi^2 = 1$; that is $\frac{r^2}{a'^2} + \frac{s^2}{b'^2} + \frac{z^2}{c'^2} = 1.$

When all these equations are satisfied, the terms within the brackets will be the same, and as the integrals are to be taken between the same limits, the attraction of the first spheroid on the first point perpendicular to a principal section, is to the attraction of the second spheroid on the second point perpendicular to the corresponding section as $a\,b$ to $a'\,b'$, that is as the area of the section of the first to the area of the section in the second.

(50.) The utility of this proposition arises from this circumstance, that if the first point be *without* the first ellipsoid, the second point will be *within* the second ellipsoid, the attraction of which has already been found. For $a^2 - c^2 = a'^2 - c'^2$, or $a^2 - a'^2 = c^2 - c'^2$; similarly $b^2 - b'^2 = c^2 - c'^2$; hence the spheroids will not cut one another (if concentric and similarly situated.) Also since $\mu^2 + \nu^2 + \pi^2 = 1$, or $\frac{r'^2}{a^2} + \frac{s'^2}{b^2} + \frac{z'^2}{c^2} = 1$, the second point is on the surface of the first spheroid; and similarly the first point is on the surface of the second spheroid; therefore, the surface of the second spheroid is without that of the first, and, therefore, the second point is completely surrounded by the second surface.

(51.) This proposition we have demonstrated in its most general form, because the demonstration is thus made somewhat easier. We shall now return to the case which more immediately concerns us, where the semi-axes of the attracting spheroid are b, $b\,(1+e)$, and $b\,(1+e)$, and the coordinates of the attracted point r and z, s being 0.

(52.) Let b', $b'\,(1+e')$, r', and z', be the corresponding quantities in the imaginary spheroid and attracted point; then we must have $b'^2\,(1+e')^2 - b'^2 = b^2\,(1+e)^2 - b^2$; or neglecting e^2, e'^2, $b'^2\,e' = b^2\,e$, and $e' = \frac{b^2}{b'^2}e$. Also $\frac{z^2}{b'^2} + \frac{r^2}{b'^2\,(1+e')^2} = 1$, or $\frac{z^2}{b'^2} + \frac{r^2}{b'^2 + 2\,b^2\,e} = 1$, or $\frac{z^2 + r^2}{b'^2} - \frac{2\,b^2\,r^2}{b'^4}\,e = 1$; or (taking the reciprocal) $\frac{b'^2}{z^2 + r^2} + \frac{2\,b^2\,r^2}{(z^2 + r^2)^2}\,e = 1$, whence $b'^2 = z^2 + r^2 - \frac{2\,b^2\,r^2}{z^2 + r^2}\,e$, and $b' = \sqrt{z^2 + r^2} - \frac{b^2\,r^2}{(z^2 + r^2)^{\frac{3}{2}}}\,e$.

Then the attraction of the fictitious spheroid on the fictitious point in the direction of z, by (41.), is $-\frac{4\,\pi}{3}\,.\,\rho \times \left(1 + \frac{4}{5}\,e'\right).\,z' = -\frac{4\,\pi}{3}\,\rho\left(1 + \frac{4}{5}\,e'\right)\frac{b}{b'}\,.\,z$; and, therefore, by (49.), the attraction of the real spheroid on the real point is $\frac{b^2\,(1+e)^2}{b'^2\,(1+e')^2} \times -\frac{4\,\pi}{3}\,\rho\left(1 + \frac{4}{5}\,e'\right)\frac{b}{b'}\,z, = -\frac{4\,\pi}{3}\,.\,\rho\,.\,z\,.\,\frac{b^3}{b'^3}\left(1 + 2\,e - \frac{6}{5}\,e'\right)$. And the attraction of the fictitious spheroid on the fictitious point in the direction of r by (42.) is $-\frac{4\,\pi}{3}\,\rho\left(1 - \frac{2}{5}\,e'\right)r' = -\frac{4\,\pi}{3}\,\rho\,.\left(1 - \frac{2}{5}\,e'\right).\,\frac{b\,(1+e)}{b'\,(1+e')}\,r$; therefore the attraction of the real spheroid on the real point is

$$\frac{b^2\,(1+e)}{b'^2\,(1+e')} \times -\frac{4\,\pi}{3}\,\rho\,.\left(1 - \frac{2}{5}\,e'\right).\,\frac{b\,(1+e)}{b'\,(1+e')}\,.\,r = -\frac{4\,\pi}{3}\,\rho\,.\,r\,.\,\frac{b^3}{b'^3}\,.\left(1 + 2\,e - \frac{12}{5}\,e'\right).$$

(53.) Putting for $\frac{b^3}{b'^3}$ its value $\frac{b^3}{\overline{z^2 + r^2}|^{\frac{3}{2}}}\left(1 + \frac{3\,b^2\,r^2}{(z^2 + r^2)^2}\,e\right)$, and for e' its value $\frac{b^2}{z^2 + r^2}\,e$, we find

Expressions for the attraction of a homogeneous spheroid on a point without it.

attraction of spheroid in the direction of z

$$= -\frac{4\,\pi}{3}\,\rho\left\{\frac{z}{(z^2 + r^2)^{\frac{3}{2}}}\,.\,b^3\,(1 + 2\,e) + \frac{9\,r^2\,z - 6\,z^3}{5\,(z^2 + r^2)^{\frac{7}{2}}}\,.\,b^5\,.\,e\right\};$$

attraction of spheroid in the direction of r

$$= -\frac{4\,\pi}{3}\,\rho\left\{\frac{r}{(z^2 + r^2)^{\frac{3}{2}}}\,.\,b^3\,(1 + 2\,e) + \frac{3\,r^3 - 12\,r\,z^2}{5\,(z^2 + r^2)^{\frac{7}{2}}}\,.\,b^5\,e\right\}$$

(54.) From this we find the attraction of a thin stratum bounded by two spheroidal surfaces in the same manner as in (44.). If we suppose the spheroid in fig. 14 to be surrounded by a concentric spheroid, whose axis and ellipticity are $b + d\,b$ and $e + d\,e$, we shall have, in the direction of z,

Attraction of a spheroidal homogeneous shell on a point without it

attraction of large spheroid

$$= -\frac{4\,\pi}{3}\,\rho\left\{\frac{z}{(z^2 + r^2)^{\frac{3}{2}}}\left\{b^3\,(1 + 2\,e) + d\,.\,\overline{b^3\,(1 + 2\,e)}\right\} + \frac{9\,r^2\,z - 6\,z^3}{5\,(z^2 + r^2)^{\frac{7}{2}}}\,(b^5\,e + d\,.\,b^5\,e)\right\},$$

attraction of small spheroid

$$= -\frac{4\,\pi}{3}\,\rho\left\{\frac{z}{(z^2 + r^2)^{\frac{3}{2}}}\,.\,b^3\,(1 + 2\,e) + \frac{9\,r^2\,z - 6\,z^3}{5\,(z^2 + r^2)^{\frac{7}{2}}}\,b^5\,e\right\}.$$

The difference, or the attraction of the included stratum,

$$= -\frac{4\pi}{3}\rho . \left\{\frac{z}{(z^2+r^2)^{\frac{3}{2}}} . d . \overline{b^3(1+2e)} + \frac{9r^2z-6z^3}{5(z^2+r^2)^{\frac{7}{2}}} d . b^5 e\right\}$$

(55.) From this, by reasoning precisely similar to that in (44.), we find that the attraction of an assemblage of strata of different densities, each of which is bounded by spheroidal surfaces, concentric and similarly situated, as in fig. 16, on a point without it, in the direction of z, is

$$-\frac{4\pi}{3}\left\{\frac{z}{(z^2+r^2)^{\frac{3}{2}}}\int\rho . d . \overline{b^3(1+2e)} + \frac{9r^2z-6z^3}{5(z^2+r^2)^{\frac{7}{2}}}\int\rho . d . b^3 e\right\}.$$

The integrals in this expression must in general be taken from $b=0$ to $b=$ some assigned value. Let $\int\rho . d . \overline{b^3(1+2e)}$, corrected so as to vanish when $b=0$, be called $\phi(b)$; let $\int\rho . d . b^5 e$ be called $\psi(b)$; then the attraction in the direction of z

Attraction of a series of spheroidal shells of different densities on a point without them.

$$= -\frac{4\pi}{3}\left\{\frac{z}{(z^2+r^2)^{\frac{3}{2}}}\phi(b) + \frac{9r^2z-6z^3}{5(z^2+r^2)^{\frac{7}{2}}} . \psi(b)\right\}.$$

Similarly the attraction in the direction of r

$$= -\frac{4\pi}{3}\left\{\frac{r}{(z^2+r^2)^{\frac{3}{2}}}\phi(b) + \frac{3r^3-12rz^2}{5(z^2+r^2)^{\frac{7}{2}}}\psi(b)\right\}.$$

(56.) We can now express the force which acts upon any point P, in any one of the strata in such a system as we have described, fig. 17. We must use the expressions that we have just found, taking the integrals from $b=0$ to $b=$ C D, D P being the spheroidal surface of equal density that passes through P, and the expressions of (44.), taking the integrals from $b=$ C D to $b=$ C A.

(57.) Let C D $=\beta$, C A $=$ b; let the corresponding ellipticities be ϵ and e. Then the whole forces acting on P (taking into account the centrifugal force) are
force in the direction of r

$$= -\frac{4\pi}{3}\left\{\frac{r}{(z^2+r^2)^{\frac{3}{2}}}\phi(\beta) + \frac{3r^3-12rz^2}{5(z^2+r^2)^{\frac{7}{2}}}\psi(\beta)\right\} + \frac{8\pi}{15}r . \{\lambda(\text{b}) - \chi(\beta)\} + \frac{4\pi^2 r}{\text{T}^2},$$

force in the direction of z

$$= -\frac{4\pi}{3} . \left\{\frac{z}{(z^2+r^2)^{\frac{3}{2}}}\phi(\beta) + \frac{9r^2z-6z^3}{5(z^2+r^2)^{\frac{7}{2}}}\psi(\beta)\right\} - \frac{16\pi}{15} . z\{\chi(\text{b}) - \chi(\beta)\}.$$

And if we resolve the former into forces in the direction of x and y, and observe that $r^2 = x^2 + y^2$, we shall finally obtain

Attraction of a heterogeneous spheroid on one of its particles.

$$\text{X} = -\frac{4\pi}{3}\left\{\frac{x}{(x^2+y^2+z^2)^{\frac{3}{2}}}\phi(\beta) + \frac{3x(x^2+y^2)-12xz^2}{5(x^2+y^2+z^2)^{\frac{7}{2}}}\psi(\beta) - \frac{2}{5}x\{\chi(\text{b}) - \chi(\beta)\} - \frac{3\pi}{\text{T}^2}x\right\}.$$

$$\text{Y} = -\frac{4\pi}{3}\left\{\frac{y}{(x^2+y^2+z^2)^{\frac{3}{2}}}\phi(\beta) + \frac{3y(x^2+y^2)-12yz^2}{5(x^2+y^2+z^2)^{\frac{7}{2}}}\psi(\beta) - \frac{2}{5}y\{\chi(\text{b}) - \chi(\beta)\} - \frac{3\pi}{\text{T}^2}y\right\}.$$

$$\text{Z} = -\frac{4\pi}{3}\left\{\frac{z}{(x^2+y^2+z^2)^{\frac{3}{2}}}\phi(\beta) + \frac{9z(x^2+y^2)-6z^3}{5(x^2+y^2+z^2)^{\frac{7}{2}}}\psi(\beta) + \frac{4}{5}z\{\chi(\text{b}) - \chi(\beta)\}\right\}.$$

(58.) Now we have explained in (10.) and (37.) that the equation to the surface bounding a stratum of equal density, must be $\text{X}\,dx + \text{Y}\,dy + \text{Z}\,dz = 0$; and that this condition is sufficient. But our whole investigation has gone on the supposition that the surface bounding a stratum of equal density is a spheroid, whose semi-axis and ellipticity are β and ϵ, and which is, therefore, defined by the equation $\frac{x^2+y^2}{\beta^2(1+\epsilon)^2} + \frac{z^2}{\beta^2} = 1$, or $\frac{x}{1+2\epsilon}dx + \frac{y}{1+2\epsilon}dy + z\,dz = 0$. The single question then now remains:—is this consistent with the equation $\text{X}\,dx + \text{Y}\,dy + \text{Z}\,dz = 0$? or can the coefficients have the same proportions? In this inquiry we are not to take into account the squares or higher powers of ϵ, as they have been uniformly neglected.

(59.) Assuming the coefficients in the two differential equations to have the same proportion, we get this equation,

$$0 = \frac{2\epsilon . \phi(\beta)}{(x^2+y^2+z^2)^{\frac{3}{2}}} - \frac{6}{5}\frac{\psi(\beta)}{(x^2+y^2+z^2)^{\frac{5}{2}}} - \frac{6}{5}\{\chi(\text{b}) - \chi(\beta)\} - \frac{3}{\text{T}^2},$$

Earth supposed heterogeneous.

in which we have omitted the terms $\epsilon \,.\, \psi(\beta)$, $\epsilon \,.\, \{\chi(\mathrm{b}) - \chi(\beta)\}$, and $\epsilon \,.\, \frac{3\pi}{\mathrm{T}^2}$, because an inspection of the quantities by whose integration the functions are produced will show that though $\phi(\beta)$ is not small, yet $\psi(\beta)$ and $\chi(\beta)$ depend entirely upon e for their value, and, therefore, $\epsilon \,.\, \psi(\beta)$ and $\epsilon \,.\, \chi(\beta)$ are in fact of the second order with regard to ϵ. And $\frac{3\pi}{\mathrm{T}^2}$, which is a multiple of the centrifugal force, is to be estimated of the same order as ϵ, because the ellipticity is immediately occasioned by it, and, therefore, $\epsilon \,.\, \frac{3\pi}{\mathrm{T}^2}$ is also of the second order.

(60.) Again, the quantity $x^2 + y^2 + z^2$, which is in the denominator of the first two terms, differs from β^2 only by $\frac{(x^2 + y^2)(2\epsilon + \epsilon^2)}{\beta^2 (1 + \epsilon)^2}$, that is by a quantity of the same order as ϵ, and, therefore, it may be considered in this equation as equal to β^2. The equation now becomes

$$0 = \frac{2\epsilon \,.\, \phi(\beta)}{\beta^3} - \frac{6}{5} \,.\, \frac{\psi(\beta)}{\beta^5} - \frac{6}{5}\{\chi(\mathrm{b}) - \chi(\beta)\} - \frac{3\pi}{\mathrm{T}^2};$$

or putting b for β,

$$\frac{2e \,.\, \phi(b)}{b^3} - \frac{6}{5}\frac{\psi(b)}{b^5} - \frac{6}{5}\{\chi(\mathrm{b}) - \chi(b)\} - \frac{3\pi}{\mathrm{T}^2} = 0:$$

and if this equation is possible, the equilibrium is possible.

Equilibrium is possible, with the form assumed.

(61.) Differentiating this equation twice, so as to eliminate $\psi(b)$ and $\chi(b)$, both which contain e, and observing that as $\phi(b)$ is multiplied by e, we may consider it as $= \int \rho \,.\, d\,(b^3)$, instead of $= \int \rho \,.\, d\,(b^3 \,.\, \overline{1 + 2e})$, we find

$$b^3 \phi(b) \,.\, \frac{de}{db} + 3\,\psi(b) - 3\,e \,.\, b^2 \phi(b) = 0,$$

$$\frac{d^2 e}{d b^2} + \frac{2\rho b^2}{\int \rho b^2 db} \,.\, \frac{de}{db} + \left(\frac{2\rho b}{\int \rho b^2 db} - \frac{6}{b^2}\right) e = 0.$$

Upon expressing ρ in terms of b it will be possible to solve this equation, and to obtain e in terms of b. The solution will contain two arbitrary constants, whose values may be determined by making the expression satisfy the original equation. Hence equilibrium is possible.

(62.) Using the letter m (as in the investigation of the form assumed by a homogeneous fluid) to denote the ratio of the centrifugal force at the Equator to the force of Gravity there, and observing that at the surface $\beta = \mathrm{b}$, $x = \mathrm{b}\,(1 + \mathrm{e})$, $y = 0$, $z = 0$, we have

$$m = \frac{\frac{3\pi}{\mathrm{T}^2}\mathrm{b}\,(1 + \mathrm{e})}{\frac{\phi(\mathrm{b})}{\mathrm{b}^2 (1 + \mathrm{e})^2} + \frac{3}{5}\frac{\psi(\mathrm{b})}{\mathrm{b}^4 (1 + \mathrm{e})^4} - \frac{3\pi}{\mathrm{T}^2}\mathrm{b}\,(1 + \mathrm{e})};$$

Equation to be used for investigation of the Earth's form.

and neglecting the terms of the second order, $m = \frac{3\pi}{\mathrm{T}^2} \,.\, \frac{\mathrm{b}^3}{\phi(\mathrm{b})}$; whence $\frac{3\pi}{\mathrm{T}^2} = \frac{m\,\phi(\mathrm{b})}{\mathrm{b}^3}$. The equation of (60.), in the form in which we are compelled to use it for investigation of the Earth's constitution, is, therefore,

$$\frac{2e \,.\, \phi(b)}{b^3} - \frac{6}{5} \,.\, \frac{\psi(b)}{b^5} - \frac{6}{5}\{\chi(\mathrm{b}) - \chi(b)\} - \frac{m\,\phi(\mathrm{b})}{\mathrm{b}^3} = 0.$$

We have already remarked in (11.) that this equation also holds if we suppose the density of the fluid to depend on the pressure. We may further remark that if we suppose a solid nucleus to exist, similar in general constitution to what we have assumed to be the state of the Earth, but having for its different strata any arbitrary densities and ellipticities, and then if we suppose fluids of different densities to be suffered to arrange themselves freely round this nucleus, the same expressions will hold for the forces, as if the whole were fluid, (the integrals being taken as well for the solid as for the fluid part,) and the equation of this article will apply in the same manner with regard to the fluid parts. And, therefore, the equations respecting the surface (which are in fact the only important ones, the others being only useful in conducting us to them) are equally true whether the whole be supposed to be fluid, or a fluid heterogeneous mass be supposed to surround such a nucleus.

Equation simplified when applied to the surface.

(63.) At the surface $b = \mathrm{b}$; and the equation of the last article becomes $(2\mathrm{e} - m)\frac{\phi(\mathrm{b})}{\mathrm{b}^3} - \frac{6}{5} \,.\, \frac{\psi(\mathrm{b})}{\mathrm{b}^5} = 0.$

(64.) One of the most remarkable applications of this equation is to be found in the expression for Gravity at any part of the Earth's surface. If in (57.) we put b for b, and $\frac{m\,\phi(\mathrm{b})}{\mathrm{b}^3}$ for $\frac{3\pi}{\mathrm{T}^2}$, we have for the forces acting on a point at the Earth's surface

$$X = -\frac{4\pi}{3}\left\{\frac{x}{(x^2+y^2+z^2)^{\frac{3}{2}}}\phi(\mathrm{b}) + \frac{3x(x^2+y^2) - 12xz^2}{5(x^2+y^2+z^2)^{\frac{7}{2}}}\psi(\mathrm{b}) - x\frac{m\phi(\mathrm{b})}{\mathrm{b}^3}\right\}.$$

$$Y = -\frac{4\pi}{3}\left\{\frac{y}{(x^2+y^2+z^2)^{\frac{3}{2}}}\phi(\mathrm{b}) + \frac{3y(x^2+y^2) - 12yz^2}{5(x^2+y^2+z^2)^{\frac{7}{2}}}\psi(\mathrm{b}) - y\frac{m\phi(\mathrm{b})}{\mathrm{b}^3}\right\}.$$

$$Z = -\frac{4\pi}{3}\left\{\frac{z}{(x^2+y^2+z^2)^{\frac{3}{2}}}\phi(\mathrm{b}) + \frac{9z(x^2+y^2) - 6z^3}{5(x^2+y^2+z^2)^{\frac{7}{2}}}\psi(\mathrm{b})\right\}.$$

Expression for Gravity at the Earth's surface.

The whole force or $\sqrt{X^2+Y^2+Z^2}$, putting r^2 for x^2+y^2, and neglecting terms of the second order, is

$$\frac{4\pi}{3}\left\{\frac{\phi(\mathrm{b})}{r^2+z^2} + \frac{3}{5}\cdot\frac{r^2-2z^2}{(r^2+z^2)^3}\psi(\mathrm{b}) - \frac{r^2}{(r^2+z^2)^{\frac{1}{2}}}\cdot\frac{m\phi(\mathrm{b})}{\mathrm{b}^3}\right\}.$$

Now the equation to the external surface is $\frac{r^2}{\mathrm{b}^2(1+\mathrm{e})^2} + \frac{z^2}{\mathrm{b}^2} = 1$, whence $r^2 + z^2 = \mathrm{b}^2 + 2\,\mathrm{e}\,r^2$; or if λ be the latitude, we may assume (nearly enough to the truth for substitution in the small terms) $r^2 = \mathrm{b}^2 . \cos^2\lambda$; whence $r^2 + z^2 = \mathrm{b}^2(1 + 2\,\mathrm{e} . \cos^2\lambda) = \mathrm{b}^2(1 + 2\,\mathrm{e} - 2\,\mathrm{e}\sin^2\lambda)$. Hence $r^2 - 2z^2 = \mathrm{b}^2(1 - 3\sin^2\lambda)$, omitting e, as this expression is used only to multiply a small term; and $\frac{r^2-2z^2}{(r^2+z^2)^3} = \frac{1-3\sin^2\lambda}{\mathrm{b}^4}$. Also $\frac{r^2}{(r^2+z^2)^{\frac{1}{2}}} = \mathrm{b}(1-\sin^2\lambda)$. Substituting, we get for the whole force

$$\frac{4\pi}{3}\left\{\frac{\phi(\mathrm{b})}{\mathrm{b}^2}(1 - 2\,\mathrm{e} + 2\,\mathrm{e}\sin^2\lambda) + \frac{3}{5}\cdot\frac{\psi(\mathrm{b})}{\mathrm{b}^4}(1 - 3\sin^2\lambda) - \frac{m\phi(\mathrm{b})}{\mathrm{b}^2}(1 - \sin^2\lambda)\right\}$$

$$= \frac{4\pi}{3}\cdot\frac{\phi(\mathrm{b})}{\mathrm{b}^2}\cdot\left(1 - 2\,\mathrm{e} - m + \frac{3}{5}\cdot\frac{\psi(\mathrm{b})}{\mathrm{b}^2\phi(\mathrm{b})}\right)\cdot\left\{1 + \overline{2\,\mathrm{e} - \frac{9}{5}\,\frac{\psi(\mathrm{b})}{\mathrm{b}^2 . \phi(\mathrm{b})} + m} . \sin^2\lambda\right\}.$$

Let

$$\frac{4\pi}{3}\cdot\frac{\phi(\mathrm{b})}{\mathrm{b}^2}\cdot\left(1 - 2\,\mathrm{e} - m + \frac{3}{5}\cdot\frac{\psi(\mathrm{b})}{\mathrm{b}^2\phi(\mathrm{b})}\right) = \mathrm{E};$$

Gravity expressed in terms of the latitude.

then the expression for Gravity is

$$\mathrm{E}\left\{1 + \left(2\,\mathrm{e} - \frac{9}{5}\cdot\frac{\psi(\mathrm{b})}{\mathrm{b}^2 . \phi(\mathrm{b})} + m\right)\sin^2\lambda\right\};$$

from which it appears that, in going from the Equator to the Poles, Gravity increases as the square of the sine of latitude.

(65.) The coefficient of the square of the sine of latitude is $2\,\mathrm{e} - \frac{9}{5}\cdot\frac{\psi(\mathrm{b})}{\mathrm{b}^2 . \phi(\mathrm{b})} + m$. Now from (63.) we get $\frac{9}{5}\cdot\frac{\psi(\mathrm{b})}{\mathrm{b}^2 . \phi(\mathrm{b})} = 3\,\mathrm{e} - \frac{3m}{2}$. Substituting, the coefficient of $\sin^2\lambda$ is $\frac{5m}{2} - \mathrm{e}$; and Gravity is now expressed by $\mathrm{E}\left(1 + \overline{\frac{5m}{2} - \mathrm{e}} . \sin^2\lambda\right)$, a remarkably simple expression, all functions, and, in fact, every thing depending on the internal constitution of the spheroid having disappeared. It appears from this, that if by observations of the force of Gravity at different latitudes we can express it by a formula of this kind $\mathrm{E}(1 + \mathrm{F}\sin^2\lambda)$, then e, the ellipticity of the Earth's surface, will $= \frac{5m}{2} - \mathrm{F}$. This is the celebrated theorem known by the name of *Clairaut's Theorem*.

Clairaut's theorem.

(66.) Another remarkable application of the equation of (63.) occurs in the expression for the attraction of a point exterior to the spheroid. The forces in the directions of r and z will be found by putting b for b in the expressions of (55.); resolving these into forces in the directions of x, y, and z, and calling them X′, Y′, Z′, we have

Attraction of heterogeneous spheroid on a point without it.

$$X' = -\frac{4\pi}{3}\cdot\left\{\frac{x}{(x^2+y^2+z^2)^{\frac{3}{2}}}\phi(\mathrm{b}) + x\,\frac{3(x^2+y^2) - 12z^2}{5(x^2+y^2+z^2)^{\frac{7}{2}}}\psi(\mathrm{b})\right\}.$$

$$Y' = -\frac{4\pi}{3}\cdot\left\{\frac{y}{(x^2+y^2+z^2)^{\frac{3}{2}}}\phi(\mathrm{b}) + y\,\frac{3(x^2+y^2) - 12z^2}{5(x^2+y^2+z^2)^{\frac{7}{2}}}\psi(\mathrm{b})\right\}.$$

$$Z' = -\frac{4\pi}{3}\cdot\left\{\frac{z}{(x^2+y^2+z^2)^{\frac{3}{2}}}\phi(\mathrm{b}) + z\,\frac{9(x^2+y^2) - 6z^2}{5(x^2+y^2+z^2)^{\frac{7}{2}}}\psi(\mathrm{b})\right\}.$$

Physical Theory. Earth supposed heterogeneous.

Substituting for $\frac{3 . \psi (b)}{5}$ the value $\left(e - \frac{m}{2}\right) . b^2 . \phi (b)$ found in (63.), and making $\frac{4 \pi}{3} . \phi (b) = M$, we have

$$X' = - M \left\{ \frac{x}{(x^2 + y^2 + z^2)^{\frac{3}{2}}} + x \frac{b^2 (x^2 + y^2 - 4 z^2)}{(x^2 + y^2 + z^2)^{\frac{7}{2}}} \left(e - \frac{m}{2}\right) \right\}.$$

$$Y' = - M \left\{ \frac{y}{(x^2 + y^2 + z^2)^{\frac{3}{2}}} + y \frac{b^2 (x^2 + y^2 - 4 z^2)}{(x^2 + y^2 + z^2)^{\frac{7}{2}}} \left(e - \frac{m}{2}\right) \right\}.$$

$$Z' = - M \left\{ \frac{z}{(x^2 + y^2 + z^2)^{\frac{3}{2}}} + z \frac{b^2 (3 x^2 + 3 y^2 - 2 z^2)}{(x^2 + y^2 + z^2)^{\frac{7}{2}}} \left(e - \frac{m}{2}\right) \right\}.$$

It appears, then, that the attraction of a spheroid upon a body without it is not in the direction of a line joining the body with the centre of the spheroid; (for if it were, X′, Y′, Z′ would be proportional to x, y, z respectively;) and, in consequence, the motion of the satellite of a spheroidal body will not be the same as if the body were spherical. The irregularity occasioned by this difference is sensible in the motion of our own Moon, and in those of Jupiter's satellites; and as it depends on $e - \frac{m}{2}$, it gives us the means of ascertaining the value of e without any knowledge of the internal constitution of the Earth.

Resulting inequality in the Moon's motion.

(67.) We cannot here go through the whole process of calculating the inequality of the Moon produced by the Earth's ellipticity, but we can indicate the principal steps. Let the axis of x be supposed to be directed to the first point of Aries, that of y to the point in the Equator whose right ascension is 90°, and that of z to the pole of the Equator. Now take a new system of coordinates, that of x being the same as before, that of y' in the plane of the Ecliptic directed to the first point of Cancer, and that of z' directed to the pole of the Ecliptic. Resolve the three forces X′, Y′, Z′ in these three directions. From the Moon let fall a perpendicular on the plane of the Ecliptic, and join the Earth's centre with the foot of the perpendicular, and resolve the forces just found into one in the direction of the joining line, one in the direction of the perpendicular, and one at right angles to both these. Let θ be the Moon's longitude, ω the obliquity of the Ecliptic. Then it will be found that the last-mentioned forces are $X' \cos \theta + (Y' \cos \omega + Z' \sin \omega) \sin \theta$, $Z' \cos \omega - X' \sin \omega$, and $X' \sin \theta - (Y' \cos \omega + Z' \sin \omega) \cos \theta$. Adopting the notation in the Treatise on PHYSICAL ASTRONOMY, Part III., and substituting for x, y, z the values $\frac{1}{u} \cos \theta$, $\frac{1}{u} (\sin \theta . \cos \omega - s \sin \omega)$, $\frac{1}{u} (\sin \theta . \sin \omega + s \cos \omega)$, we find the terms depending on the Earth's ellipticity which are to be added to $m' V$, $m' T$, and $m' \frac{d \Omega}{d z}$. (See PHYSICAL ASTRONOMY.) They are rather complicated, but the only terms which produce any sensible effect are in $m' T$, $- M \left(e - \frac{m}{2}\right) . 2 b^2 u^4 . \sin \omega . \cos \omega . \cos \theta . s$; and in $m' \frac{d \Omega}{d z}$, $M \left(e - \frac{m}{2}\right) \times 2 b^2 u^4 \sin \omega . \cos \omega . \sin \theta$. If we treat these terms like the others in the Treatise alluded to, it will easily be found that the resulting inequality in the Moon's latitude, expressed in seconds, (considering the sum of the masses of the Earth and Moon = 1) is $- \frac{4 . \overline{60}|^3}{\pi} . \overline{e - \frac{m}{2}} . \left(\frac{\text{Earth's period}}{\text{Moon's period}}\right)^2 \left(\frac{\text{Earth's radius}}{\text{Moon's distance}}\right)^2 . \sin \omega . \cos \omega . \sin \theta = - \overline{e - \frac{m}{2}} . 4891'' . \sin \theta$ nearly. The perturbation in longitude is not so easily calculated.

Law of density which makes the equation for the ellipticity of the different strata integrable.

(68.) We shall conclude this investigation with remarking that the differential equation of (61.) may be put in a simpler form by assuming $\int \rho b^2 d b = p$, and $p e = v$; substituting these values,

$$\frac{d^2 v}{d b^2} - \frac{6 v}{b^2} - v \frac{b}{p} . \frac{d p}{d b} = 0.$$

A form of ρ which makes this easily integrable, (first pointed out, we believe, by Legendre,) and which probably represents pretty well the law of density in the interior of the Earth, (giving a density gradually increasing to the centre,) is $\rho = A \frac{\sin q b}{b}$, A and q being constant. The general value of v is found to be $C (\sin \overline{q b + C'} + \frac{3}{q b} \cos \overline{q b + C'} - \frac{3}{q^2 b^2} \sin \overline{q b + C'})$, and determining the constants by substitution in the equations from which this differential equation is derived, it is found that e, or $\frac{v}{p}$, =

$$\frac{5 m}{2} . \frac{\left(1 - \frac{q b}{\tan q b}\right)^2}{2 - q^2 b^2 - \frac{q b}{\tan q b} - \frac{q^2 b^2}{\tan^2 q b}} . \frac{1 - \frac{3}{q^2 b^2} + \frac{3}{q b . \tan q b}}{1 - \frac{q b}{\tan q b}}.$$

Figure of the Earth.

To get the ellipticity of the surface we must put b for b, and if $f = 1 - \frac{q\,\mathrm{b}}{\tan q\,\mathrm{b}}$, it is found that $e = \frac{5m}{2} \cdot \frac{1 - \frac{3f}{q^2 \mathrm{b}^2}}{3 - f - \frac{q^2 \mathrm{b}}{f}}$. The value $q = \frac{5}{6} \cdot \frac{\pi}{\mathrm{b}}$ gives a law of density that probably represents nearly the Earth's density.

The probable error, arising from neglect of the higher powers of the ellipticity, may be inferred from those in the extreme cases.

(69.) We shall now consider the probable magnitude of the error which we have incurred by neglecting the square of the ellipticity. We have investigated, accurately, two cases which may be considered as extremes in the series of laws of density, within which the law of the Earth's density is included. One of these is, the case of a homogeneous Fluid; the other is that of (12.), in which the assumption of attraction directed only to the centre, amounts to the same as (on the principle of gravitation) the assumption that the matter near the centre is infinitely more dense than that near the surface. We shall examine, then, how far, in these two cases, the two principal results of our investigation (the ellipticity of form, and Clairaut's theorem) are true; and if we find them nearly true in these cases, we shall conclude that they are nearly true in the case of a density gradually increasing to the centre.

If the Fluid be homogeneous, the form is accurately elliptic

(70.) First as to the ellipticity of figure. When the Fluid is homogeneous, it appears by the investigation extending from (14.) to 26.), that the figure is *accurately* that of an elliptic spheroid. When the attraction of the particles is neglected in comparison with the attraction to the centre, it appears from (12.) that the equation to the external surface, using r for the distance of any point from the centre, is

$$\frac{1}{r} = \frac{2+3m}{2+2m} \cdot \frac{1}{a} - \frac{m}{2+2m} \cdot \frac{x^2+y^2}{a^3}, \text{ or } \frac{1}{r} = \frac{1}{b} - \left(\frac{a}{b} - 1\right) \cdot \frac{x^2+y^2}{a^3} = \frac{1}{b} - \frac{e}{b^3(1+e)^3}(x^2+y^2).$$

Let r' be the corresponding line in an elliptic spheroid with the same axes for the same values of x and y; then proceeding from the equation $\frac{x^2+y^2}{a^2} + \frac{z^2}{b^2} = 1$, it will be found that

$$r' = b\sqrt{\left\{1 + \frac{a^2-b^2}{a^2 b^2} \cdot (x^2+y^2)\right\}} = b\sqrt{\left\{1 + \frac{2e+e^2}{1+2e+e^2} \cdot \frac{x^2+y^2}{b^2}\right\}}.$$

Expanding the expressions for r and r' as far as terms of the order e^2, it is found that $r' - r = \frac{3}{2b^3}e^2 \cdot (x^2+y^2) \cdot (b^2 - \overline{x^2+y^2})$. This is greatest when $x^2+y^2 = \frac{b^2}{2}$, or at latitude 45° nearly; its value is then $\frac{3e^2}{8}b$. If $b = 4000$ miles, and $e = \frac{1}{580}$, (the ellipticity of the Earth that would correspond to this supposition,) this would be 24 feet, a quantity quite insensible. We may conclude, then, that the theoretical figure of a heterogeneous Fluid, on the principle of Gravitation, would (since r is less than r') be somewhat flatter at latitude 45° than the elliptic spheroid, but that if the circumstances were those of the Earth, the difference would be insensible in measures of degrees.

If the Fluid be infinitely dense at the centre, the form does not sensibly differ from an elliptic spheroid.

(71.) Secondly, as to the law of Gravity at the surface. In the homogeneous ellipsoid it has been found (35.) that, putting λ for the latitude of any point, the Gravity there is proportional to $\frac{1}{\sqrt{\sin^2\lambda + \overline{1+e}|^2 \cos^2\lambda}}$. Expanding this so as to include the second power of e, it may be put under the form $(1 - e + e^2)\ \{1 + e\sin^2\lambda\ \frac{3e^2}{2}\sin^2\lambda\cos^2\lambda\}$, or Gravity is proportional to $\{1 + e\sin^2\lambda - \frac{3e^2}{2}\sin^2\lambda \cdot \cos^2\lambda\}$. Now as Clairaut's theorem is commonly understood, Gravity is proportional to $\{1 + \overline{\frac{5m}{2} - e} \cdot \sin^2\lambda\}$. We must then investigate accurately the relation between e and m. In the equation of (29.) make $f = \frac{1}{\cot f} - \frac{1}{3} \cdot \frac{1}{\cot^3 f} + \frac{1}{5} \cdot \frac{1}{\cot^5 f} - \frac{1}{7} \cdot \frac{1}{\cot^7 f}$, and we find at length $\frac{m}{1+m} = \frac{4}{5}e\left(1 - \frac{57}{70}e\right)$, whence $\frac{5m}{2} = 2e - \frac{1}{35}e^2$, and $\frac{5m}{2} - e = e - \frac{1}{35}e^2$. Consequently, according to Clairaut's law, Gravity should be expressed by $1 + \left(e - \frac{e^2}{35}\right)\sin^2\lambda$; it actually is expressed by $1 + e\sin^2\lambda - \frac{3e^2}{2}\sin^2\lambda\cos^2\lambda$. We ought then to increase Gravity in the homogeneous spheroid by equatorial Gravity × $e^2\sin^2\lambda\left(\frac{3}{2}\cos^2\lambda - \frac{1}{35}\right)$ in order to make it follow Clairaut's law. For circumstances similar to those of the Earth, e must be taken $= \frac{1}{230}$, and the quantity to be added is about

If the Fluid be homogeneous, Clairaut's law is nearly true.

Physical Theory. Earth supposed heterogeneous.

$\frac{\text{equatorial Gravity}}{35300} \times \sin^2\lambda\left(\cos^2\lambda - \frac{2}{105}\right)$. This is nearly a maximum when $\lambda = 45°$, and it then is nearly $= \frac{\text{equatorial Gravity}}{140000}$, a quantity barely sensible in the most accurate pendulum experiments.

When the attractive force is wholly directed to the centre, it appears (see 12.) that the resolved parts of Gravity are

$$f\left\{\frac{x}{r^3} - (2e - 6e^2)\frac{x}{b^3}\right\}, \quad f\left\{\frac{y}{r^3} - (2e - 6e^2)\frac{y}{b^3}\right\}, \quad f\frac{z}{r^3}$$

Adding the squares of these, observing that $\frac{1}{r} = \frac{1}{b}\left\{1 - e\,.\,\frac{x^2 + y^2}{b^2} + 3e^2\frac{x^2 + y^2}{b^2}\right\}$, and extracting the square root, it is found that Gravity is proportional to

$$1 - 4e\frac{x^2 + y^2}{b^2} + 14e^2\,.\,\frac{x^2 + y^2}{b^2} + e^2\left(\frac{x^2 + y^2}{b^2}\right).$$

Now from the consideration that $\sin\lambda = \frac{\text{force in direction of } z}{\text{Gravity}}$, we find $\frac{x^2 + y^2}{b^2} = (1 + 4e)\cos^2\lambda - 2e\cos^4\lambda$; and thus we obtain at length that Gravity is proportional to

$$1 + \overline{4e + 9e^2}\sin^2\lambda - 9e^2\sin^2\lambda\cos^2\lambda.$$

But from (12.) $\frac{a}{b} = \frac{2 + 3m}{2 + 2m}$, whence $e = \frac{m}{2 + 2m}$, and $m = 2e + 4e^2$, $\frac{5m}{2} = 5e + 10e^2$, $\frac{5m}{2} - e = 4e + 10e^2$, and therefore Gravity, according to Clairaut's formula, ought to be expressed by

$$1 + \overline{4e + 10e^2}\,.\,\sin^2\lambda.$$

If the density be infinitely great at the centre, Clairaut's law is nearly true.

We ought, therefore, to increase the actual Gravity by equatorial Gravity $\times\, e^2\sin^2\lambda\,(9\cos^2\lambda + 1)$, in order to bring it under Clairaut's law. The maximum value of this is nearly $\frac{9e^2}{4} \times$ equatorial Gravity; which, if $e = \frac{1}{580}$, is about $\frac{\text{equatorial Gravity}}{150000}$; a quantity as small as that found before.

Conclusions with regard to heterogeneous spheroid.

(72.) We may conclude, then, that the following theoretical results may be considered as sufficiently accurate for a heterogeneous fluid mass in the circumstances of the Earth.

The external surface has the form of an elliptic spheroid.

At the latitude λ Gravity is proportional to $1 + \left(\frac{5m}{2} - e\right)\sin^2\lambda$, (where m is the proportion of centrifugal force at the Equator to Gravity at the Equator, and $1 : 1 + e$ is the proportion of the axes.)

Disturbance produced by a small mass near the Earth's surface.

(73.) If a mass of different density were placed any where in the Fluid it is plain that it would disturb all the laws that we have found. For a calculation of its effects we shall refer to a paper by Dr. Young, in the *Phil. Trans.* for 1819, from which we extract the following results.

Prop. A. If a plumb-line be drawn aside by a small mass not far below the Earth's surface, the distance of the points where the greatest deviations are produced, is to the depth of the mass, as $\sqrt{2}$ to 1.

B. The sine of the greatest deviation $= ,385 \times \frac{a}{c^2}$ $\left(\text{where } a = \frac{\text{disturbing mass}}{\text{Earth's mass}}, \text{ and } c = \frac{\text{depth}}{\text{Earth's radius}}\right)$.

C. The greatest elevation of the general surface above the sphere $= \frac{a}{c}$.

D. Gravity at the highest point will be increased by $\frac{a}{c^2} - \frac{2a}{c}$.

E. At the place where the greatest deviation of the plumb-line is produced, the proportional increase of Gravity is to the deviation (estimated as an arc to radius 1) as $\sqrt{2}$ to 1.

We have conducted the theoretical investigation of the Earth's form by an analysis which, though far from elegant, is sufficiently powerful to master this subject, and sufficiently simple to be understood after a common acquaintance with the Differential Calculus. The analysis of Laplace we have thought it desirable to exclude, where it is possible to succeed without its assistance. The difficulty of understanding the fundamental points of that calculus, and the obscurity which, to those who have given most attention to it, has always appeared to hang upon many of its applications, (see *Phil. Trans.* 1812, &c. and *Cambridge Transactions*, vol. iii.) will serve for our apology. We have thus lost some of Laplace's results, (especially those relating to the form of a Fluid spread over an irregular solid;) but we have thought it better to give them up at once, than to compose a treatise which, to the greater part of our readers, would be (and that without necessity) unintelligible. The reader who wishes to be acquainted with a calculus the most singular in its nature, and the most powerful in its applications that has ever appeared, is referred for explanation and example to our Essay **Electricity**, or to the Vth Book of the *Mécanique Céleste.*

Section 3.—On the Manner of determining the Figure of the Earth by Geodetic Measures.

The investigations which we have just given seem to show that if the Earth had been originally fluid, and if the different liquids of which it consisted had been allowed to settle into a state of rest, and if it had then become solidified, and had afterwards been subjected to no alteration of shape, its external form would be nearly that of an oblate spheroid. The ellipticity of the spheroid, however, is not determined; it has only appeared that if the Earth were supposed to have been a homogeneous Fluid, (a thing in the highest degree improbable,) and the attraction of each molecule proportional to its mass, the proportion of the equatorial axis to the polar axis would be 231 : 230; if the whole attraction were directed to one attractive point at the Earth's centre, or if, on the same theory of universal attraction, the density at the centre were infinitely greater than that at any other point, the proportion would be 581 : 580; and if (as seems *à priori* most probable) the density increased gradually to the centre, and if every particle attracted with a force proportional to its mass, the proportion of the axes would be between these two.

Now it is plain that none of these suppositions correspond exactly to the state of the Earth's surface. The irregularities in its external form are considerable. The height of the mountains in some parts is perhaps equal to $\frac{1}{7}$ of the difference between the polar and equatorial semiaxes. The depth of the sea in many places is possibly much greater. Still the examination of the Earth's surface will serve to verify the correctness of the general principle of Gravitation. We may expect that there will be a considerable approximation to the spheroidal form, subject to irregularities of which, in some cases, the causes cannot be discovered, and in other cases a probable explanation can be given by reference to the form of the neighbouring mountains or the surrounding country. If (as some Philosophers have supposed) the interior of the Earth be yet fluid within a small distance of the surface, it is impossible that the general form of the Earth can differ very much from that of a fluid mass.

The theory will apply, approximately, to the Earth's form.

The extent of the watery covering of the Earth is a circumstance highly favourable to the agreement of the calculated and observed forms of the Earth. We may consider the sea as a Fluid, acted on by the attraction of the solid part of the Earth, (whose form does not much differ from that of equilibrium,) and by the centrifugal force, and the reciprocal attraction of its own particles. The irregularities in the Earth's attraction will be very much smaller than those of the Earth's form; and, consequently, the irregularity which they produce in the form of the sea will be very much smaller than the irregularities in the form of the land. If, then, we refer our measures, which must necessarily be made on land, to the surface of the sea, we may expect an agreement of the theoretical form and the ascertained measures to very considerable exactness.

It is natural, therefore, that in making the comparison we should begin by discussing the properties of the spheroid. By combining with them a consideration of the practical exactness which it is possible to attain in the different measures, we shall be able to choose the kind of measure which is best adapted to our purpose. And by calculating from different combinations of measures the length of the Earth's axes and the value of its ellipticity, we can infer, from the agreement or discordance of the results, the correctness or incorrectness of our original assumptions.

Differences of latitude found astronomically.

We have explained in the first section the general principle upon which the Earth's form is ascertained by measures. If the distance between two points can be found, and if the angle can be found which is included between the verticals drawn at these points, the distance of the intersection of those verticals can be found; and this is the same as the radius of curvature of the curve joining those points. The lengths of the extensive arcs which have been used for this purpose, have always (with one exception) been ascertained by geodetic operations, for a general idea of which we refer the reader to the Essay on **Trigonometry**, § IX., and which we shall explain with greater minuteness in the following section. For the mere measure, the general direction of the chain of triangles, or the direction of the line joining the extreme points, is a matter of perfect indifference. But there are practical considerations which require us to fix on one of two directions. The latitudes of the places P and Q, fig. 18, whether on the same meridian or not, are the complements of the angles $p\,P\,s$, $q\,Q\,s$, respectively, which are included by the verticals at the places and the lines drawn to the celestial Pole. And if S be any star which can be observed at both places the angle $s\,P\,p = s\,P\,S + S\,P\,p$, and $s\,Q\,q = s\,Q\,S + S\,Q\,q$; considering, therefore, the angles $s\,Q\,s$, $s\,P\,s$, as equal, the difference of latitudes is the same as the difference of $S\,P\,p$, $S\,Q\,q$. That is, it is the same as the difference of the zenith distances of the same star at the two places, and can, therefore, easily be found. Now if the places P and Q be on the same meridian, their verticals will intersect in some point D, and the difference of latitudes, which is the difference of $s\,Q\,q$ and $s\,P\,p$, or ($P\,r$ being parallel to $Q\,q$) the difference of $s\,P\,r$ and $s\,P\,p$, is equal to $r\,P\,p$, or Q D P, the angle contained by the verticals. The length P Q being known from measures, and the angle P D Q, or the difference of latitude, being found by observations of the zenith distances of a star, the length of P D or Q D, or the radius of curvature, is found.

Again, if T and V, fig. 19, be two places on different meridians, and if planes be drawn through these places, and through the axis A C of the Earth, the angle made by these planes (or the difference of longitude) may be determined astronomically. For in consequence of the inclination of the planes, the place T will be brought by the Earth's motion under the celestial meridian passing through some known star sooner than the place V;

re of Earth.

Determination by Geodetic Measures.

Difference of longitude found astronomically.

and as the Earth's rotatory motion is uniform, the difference of time will serve to measure the angle.* If, then, we compare by any means the clocks at the two places, and observe the times indicated by these clocks at the passage of the same star over the meridians, the angle between the planes can be ascertained. Now if instead of T we have a place *t*, whose latitude is the same as that of V, and if we draw V W, *t* W, perpendicular to the axis, the angle between the planes will be the same as the angle V W *t*. The distance V *t* being measured, and the angle V W *t*, or the difference of longitude being found, the length of V W, or *t* W, or the radius of a parallel, is found.

Either of these measures then will give the length of a line that will assist materially in determining the Earth's form and dimensions. But they cannot easily be combined. Both have been extensively used; but the difference of latitude can be ascertained with so much greater accuracy than the difference of longitude, that measures of the former kind have generally been relied on.

Now in practice it is found extremely difficult to determine with accuracy the direction of any one line with respect to the meridian, or the azimuth of any station with respect to any other station. We must, therefore, always consider that we are liable to a small uncertainty in the direction of a side of one of the triangles, and, consequently, in the general direction of the chain of triangles, which depends entirely on this line. And we must choose the direction so that a small error may produce the smallest possible effect in the line to be measured.

The general direction of the chain of triangles ought to be either in the meridian or perpendicular to it.

Now, in fig. 20, let P Q be the meridian, P the first extremity of the chain of triangles, X the last; let X, *x*, Y, *y*, be in the circumference of a circle whose radius is P. Draw X Q, *x q*, Y R, *y r*, arcs of parallels. From the uncertainty in the direction of the triangles, it is uncertain perhaps whether X or *x* is the true situation of the last station. It is uncertain, therefore, whether the point in the meridian P Q, whose latitude is the same as that of the last station, is Q or *q*. But it is plain that this uncertainty is much less than it would be if Y or *y* were the situation of the last station; and that by bringing the position as near as possible to the meridian P Q, the uncertainty Q *q* may be made as small as we please. The same, it will readily be seen, is true with respect to an arc measured nearly in the direction of a parallel.

It appears, therefore, that we must determine on measuring an arc either in the direction of a meridian, or in that of a parallel; and that when we have chosen between these, we must make the general direction of the chain of triangles coincide as nearly as possible with that of the line that we have chosen.

We shall now, from the properties of the spheroid, express the length of the lines above described in terms of the axes and ellipticity of the spheroid.

Radius of parallel in a spheroid, expressed in terms of the latitude.

Let fig. 21 be the generating ellipse of the spheroid, in the position in which its plane passes through the place P; P M the normal; P N, P W, perpendiculars to the axes. Let B C = *a*, A C = *b*. Then (CONIC SECTIONS, Art. 34.) $\mathrm{N\,M} = \frac{b^2}{a^2}\,\mathrm{C\,N}$. Also P *s* being parallel to the axis, or in N P produced, and M P being produced to *p*, the angle *p* P *s* or N P M is the colatitude, and P M N the latitude of P; call this L. Then $\mathrm{N\,P} = \mathrm{M\,N}\tan\mathrm{L} = \frac{b^2}{a^2}\,\mathrm{C\,N}\,.\tan\mathrm{L}$. Now (CONIC SECTIONS, Art. 26.) $\mathrm{P\,N}^2 = \frac{b^2}{a^2}(a^2 - \mathrm{C\,N}^2)$ or $\frac{b^4}{a^4}\,\mathrm{C\,N}^2\,.\tan^2\mathrm{L} = \frac{b^2}{a^2}(a^2 - \mathrm{C\,N}^2)$, or $b^4\,.\,\mathrm{C\,N}^2\,.\tan^2\mathrm{L} = a^4 b^2 - a^2 b^2\,.\,\mathrm{C\,N}^2$, whence

$$\mathrm{C\,N}^2 = \frac{a^4}{b^2\tan^2\mathrm{L} + a^2} = \frac{a^4\cos^2\mathrm{L}}{b^2\sin^2\mathrm{L} + a^2\cos^2\mathrm{L}} = \frac{a^4\cos^2\mathrm{L}}{b^2 + (a^2 - b^2)\cos^2\mathrm{L}},\ \text{and}\ \mathrm{C\,N} = \frac{a^2\cos\mathrm{L}}{\sqrt{\{b^2 + (a^2 - b^2)\cos^2\mathrm{L}\}}}.$$

Let $a = b\,(1 + e)$; $\mathrm{C\,N} = b\,\frac{(1 + 2\,e + e^2)\cos\mathrm{L}}{\sqrt{1 + (2\,e + e^2)\cos^2\mathrm{L}}}$. If we suppose *e* so small that its square may be neglected, $\mathrm{C\,N} = \frac{b\,(1 + 2\,e)\cos\mathrm{L}}{\sqrt{1 + 2\,e\cos^2\mathrm{L}}} = b\cos\mathrm{L}\,(1 + 2\,e - e\cos^2\mathrm{L})$; or $b\cos\mathrm{L}\,(1 + e + e\sin^2\mathrm{L})$. This is the value of P W, the radius of the parallel passing through P.

Degree of parallel in terms of the latitude.

If then D be the difference of longitude expressed in seconds, of two places on the same parallel, and L their latitude, the length of the arc between them is $b\,.\cos\mathrm{L}\,(1 + e + e\sin^2\mathrm{L})\,\mathrm{D}\sin 1''$; $\mathrm{D}\sin 1''$ being the length of the arc, which with radius 1 subtends the angle D″. The length of the arc corresponding to a difference of longitude of 1° is $b\cos\mathrm{L}\,(1 + e + e\sin^2\mathrm{L})\,.\,3600\,.\sin 1''$; this is called *a degree of parallel.*

Radius of curvature of meridian in a spheroid, expressed in terms of the latitude.

The radius of curvature of the meridian is found by the expression $-\frac{\left\{1 + \left(\frac{d\,y}{d\,x}\right)^2\right\}^{\frac{3}{2}}}{\frac{d^2 y}{d\,x^2}}$, where $x = \mathrm{C\,N}$, $y = \mathrm{N\,P}$. But $y^2 = \frac{b^2}{a^2}(a^2 - x^2)$, or $b^2 x^2 + a^2 y^2 = a^2 b^2$; whence $\frac{d\,y}{d\,x} = -\frac{b^2 x}{a^2 y}$, and $\frac{d^2 y}{d\,x^2} = -\frac{b^4}{a^2 y^3}$; and the radius of curvature $= \frac{1}{b^4 a^4} \times (a^4 y^2 + b^4 x^2)^{\frac{3}{2}}$. But we have just found $x^2 = \mathrm{C\,N}^2$ or $\mathrm{P\,W}^2 = \frac{a^4\cos^2\mathrm{L}}{b^2\sin^2\mathrm{L} + a^2\cos^2\mathrm{L}}$; and

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* This angle may also be ascertained in other ways, of which we shall speak hereafter.

$y^2 = \mathrm{P\,N}^2 = \mathrm{N\,M}^2 \tan^2 \mathrm{L} = \frac{b^4}{a^4}\,\mathrm{C\,N}^2 . \tan^2 \mathrm{L} = \frac{b^4 \sin^2 \mathrm{L}}{b^2 \sin^2 \mathrm{L} + a^2 \cos^2 \mathrm{L}}$; whence the radius of curvature

$$= \frac{1}{b^4 a^4} \times \left(\frac{a^4 b^4}{b^2 \sin^2 \mathrm{L} + a^2 \cos^2 \mathrm{L}}\right)^{\frac{3}{2}} = \frac{a^2 b^2}{(b^2 \sin^2 \mathrm{L} + a^2 \cos^2 \mathrm{L})^{\frac{3}{2}}}.$$

If $a = b\,(1 + e)$, the radius of curvature $= \frac{b\,(1 + 2e + e^2)}{(1 + \overline{2e + e^2} . \cos^2 \mathrm{L})^{\frac{3}{2}}}$; or if e is so small that e^2 may be neglected, the expression becomes $b\,(1 + 2e - 3e\cos^2 \mathrm{L})$, or $b\,(1 - e + 3e\sin^2 \mathrm{L}.)$

If then λ and λ' are the latitudes of two stations on the same meridian, and if the difference between λ and λ' be not great, the included arc may be considered as a circular arc whose radius is the radius of curvature, corresponding to the middle point between them, or $b\left(1 - e + 3e\sin^2 \frac{\lambda + \lambda'}{2}\right)$. And if $\lambda' - \lambda$ be expressed in seconds, the length of the arc, subtending the angle $\lambda' - \lambda$, in a circle whose radius is 1, will be $(\lambda' - \lambda)\sin 1''$, and, therefore, the arc of meridian or the circular arc equal to it, will be $b\left(1 - e + 3e\sin^2 \frac{\lambda + \lambda'}{2}\right) . (\lambda' - \lambda) \sin 1''$.

Degree of meridian in terms of the latitude.

The length of the arc corresponding to a difference of latitudes of 1° is $b\left(1 - e + 3e\sin \frac{\lambda + \lambda'}{2}\right) . 3600 \sin 1''$; this is called *a degree of latitude.*

If, however, the arc be considerable with respect to the radius, the following process must be used. If two normals be drawn at points whose latitudes are L and L + d L, they will intersect at the distance $b\,(1 - e + 3e\sin^2 \mathrm{L})$. Let s be the arc of meridian, ds that part included betwen the latitudes L and d L, then $ds = d\mathrm{L} \times b\,(1 - e + 3e\sin^2 \mathrm{L}) = b\,d\mathrm{L} \times \left(1 + \frac{e}{2} - \frac{3e}{2}\cos 2\mathrm{L}\right)$, and $s = b \times \left(1 + \frac{e}{2}\,\mathrm{L} - \frac{3e}{4}\sin 2\mathrm{L}\right)$. This expression gives the length of the arc from the Equator to the point whose latitude is L; if then we put λ and λ' successively in place of L, and take the difference of the expressions, we shall have for the length of the arc included between the latitudes λ and λ',

$$b\left(\overline{1 + \frac{e}{2}} . \overline{\lambda' - \lambda} - \frac{3e}{4} . \overline{\sin 2\lambda' - \sin 2\lambda}\right) = b\left(\overline{1 + \frac{e}{2}} . \overline{\lambda' - \lambda} - \frac{3e}{2}\cos \overline{\lambda' + \lambda}\sin \overline{\lambda' - \lambda}\right)$$

$$= b\left(\overline{1 + \frac{e}{2}} - \frac{3e}{2} . \cos \overline{\lambda' + \lambda} . \frac{\sin \overline{\lambda' - \lambda}}{\lambda' - \lambda}\right) . (\lambda' - \lambda).$$

Here (as in all expressions given by integration) it is supposed that $\lambda' - \lambda$ is measured by its proportion to the radius; if expressed in seconds, we ought to put $(\lambda' - \lambda)\sin 1''$, and thus the length

$$= b\left\{\overline{1 + \frac{e}{2}} . - \frac{3e}{2} . \cos \overline{\lambda' + \lambda} . \frac{\sin \overline{\lambda' - \lambda}}{\lambda' - \lambda}\right\} \times (\lambda' - \lambda)\sin 1''.$$

From the former expression it will be seen that in an oblate spheroid a degree of meridian (found by making $l' - l = 3600$) near the Pole, is greater than one near the Equator, and that, generally, on increasing the latitude the degrees increase. The general fact of the oblateness of the Earth will, therefore, be proved by the augmentation of degrees in approaching the Pole; a diminution would show that the Earth's form was prolate.

The length of the axis, and the oblateness, may thus be found from two measures. Suppose λ and λ' the latitudes of the extreme points of one arc, whose length, as determined by measures, $=$ A; suppose μ, μ', and B, the extreme latitudes and measured length of another arc. Then

Ellipticity determined from two measures of meridian arcs.

$$\frac{\mathrm{A}}{(\lambda' - \lambda)\sin 1''} = b\left(1 - e + 3e\sin^2 \frac{\lambda' + \lambda}{2}\right).$$

$$\frac{\mathrm{B}}{(\mu' - \mu)\sin 1''} = \left(1 - e + 3e\sin^2 \frac{\mu' + \mu}{2}\right).$$

$$\therefore \frac{\mathrm{A}}{(\lambda' - \lambda)\sin 1''} - \frac{\mathrm{B}}{(\mu' - \mu)\sin 1''} = 3eb\left(\sin^2 \frac{\lambda' + \lambda}{2} - \sin^2 \frac{\mu' + \mu}{2}\right).$$

The value of b will be found nearly enough by neglecting e in either equation; thus $b = \frac{\mathrm{A}}{(\lambda' - \lambda)\sin 1''}$ or $= \frac{\mathrm{B}}{(\mu' - \mu)\sin 1''}$. Considering this then as known, e

$$= \frac{\frac{\mathrm{A}}{(\lambda' - \lambda)\sin 1''} - \frac{\mathrm{B}}{(\mu' - \mu)\sin 1''}}{3b\left(\sin^2 \frac{\lambda' + \lambda}{2} - \sin^2 \frac{\mu' + \mu}{2}\right)}.$$

Now, if an error should be committed in measuring either A or B, the influence of this error on the value of e would

Determination by Geodetic Measures.

depend entirely on the magnitude of the divisor $3\,b\left(\sin^2\frac{\lambda'+\lambda}{2}-\sin^2\frac{\mu'+\mu}{2}\right)$ It would be greatest when the divisor was least; and *vice versâ*. The most favourable combination, or that which would make $\sin^2\frac{\lambda'+\lambda}{2}-\sin^2\frac{\mu'+\mu}{2}$ greatest, would be one arc of which the middle was under the Equator, and another of which the middle was at the Pole. The latitudes of the middle points, or $\frac{\lambda'+\lambda}{2}$ and $\frac{\mu'+\mu}{2}$, being then, respectively, 90°, and 0, the quantity $\sin^2\frac{\lambda'+\lambda}{2}-\sin^2\frac{\mu'+\mu}{2}=1$. If the middles of the two arcs have nearly the same latitude, the divisor will be so small, and the consequent influence of errors so great, that no dependence can be placed on the value of e so determined. In general, the arcs should be separated by as wide an interval as possible. No advantage, however, is gained by measuring an arc beyond the Equator; as, on any supposition upon which investigations can be made, the degrees of meridian in South latitude ought to be equal to the degrees of meridian in the same North latitude. It is scarcely necessary to mention that if the arcs are long, and measured with accuracy, two equations should be made of the form

$$\frac{A}{(\lambda'-\lambda)\sin 1''}=b\left\{\overline{1+\frac{e}{2}}\,.\,-\frac{3\,e}{2}\,.\cos\overline{\lambda'+\lambda}\,.\,\frac{\sin\overline{\lambda'-\lambda}}{\lambda'-\lambda}\right\},$$

and should be rigorously solved for the determination of b and e.

An arc of meridian, and one of parallel, may also be combined for the same purpose. For from a measured arc of meridian we shall have the equation

$$A=b\left(1-e+3\,e\sin^2\frac{\lambda'+\lambda}{2}\right)(\lambda'-\lambda)\sin 1''.$$

Ellipticity determined from a measure of a meridian arc and a measure of an arc of parallel.

And if D be the difference of longitude (in seconds) between two places on the same parallel, whose latitude = L, and if the measured distance = C, we shall have the equation

$$C=b\cos L\,(1+e+e\sin^2 L)\,D\sin 1''.$$

Whence

$$\frac{A}{(\lambda'-\lambda)\sin 1''}-\frac{C}{D\cos L\sin 1''}=b\,e\left(3\sin^2\frac{\lambda'+\lambda}{2}-\sin^2 L-2\right),$$

and

$$e=\frac{\frac{A}{(\lambda'-\lambda)\sin 1''}-\frac{C}{D\cos L\sin 1''}}{b\left(3\sin^2\frac{\lambda'+\lambda}{2}-\sin^2 L-2\right)}=\frac{\frac{C}{D\cos L\sin 1''}-\frac{A}{(\lambda'-\lambda)\sin 1''}}{b\left(2+\sin^2 L-3\sin^2\frac{\lambda'+\lambda}{2}\right)}.$$

As before, b may be taken $=\frac{A}{(\lambda'-\lambda)\sin 1''}$, or $=\frac{C}{D\cos L\sin 1''}$. The denominator will be greatest when $\sin L$ is nearly $=1$, and $\sin\frac{\overline{\lambda'+\lambda}}{2}=0$, or when the arc of parallel is near the Pole, and that of meridian near the Equator. It will be least when $\sin^2 L$ is nearly equal to $3\sin^2.\frac{\lambda'+\lambda}{2}-2$; such a combination ought therefore to be avoided. If both arcs be measured in nearly the same latitude, the divisor is $2-2\sin^2 L$, or $2\cos^2 L$. For such measures a place near the Equator should be chosen.

In the comparison of two arcs of meridian, it appears that the greatest divisor is $3\,b$; in the comparison of one arc of meridian and one of parallel, the greatest divisor is also $3\,b$. It would, at first sight, appear that these combinations were equally advantageous. But, in fact, the difference of longitudes cannot be ascertained with so great exactness as the difference of latitudes, and larger errors may be expected in the numerator when the arc of parallel is used, than when only arcs of meridian are employed. On this account the principal reliance is placed on the comparison of meridian arcs. We believe that two arcs of parallel have never been compared; but it is plain that if they could be measured with sufficient exactness, two arcs of parallel might be used to determine the axis and ellipticity.

Elements of Earth's form may be corrected from new measures.

Instead, however, of using two measures in the way which we have described, every new measure, when the elements of the Earth's form have been approximately determined, may be employed for the purpose of correcting previous determinations. This method is now extensively used, as it bears great analogy with the process commonly employed in correcting other astronomical elements; we shall therefore describe it here. By methods which we shall discuss in the next section, when two points are connected by a chain of triangles, and the latitude of one is known, the latitude of the other can be calculated with assumed dimensions of the Earth. But this latitude may also be observed; if the observed latitude differs from that calculated, it shows that the assumed dimensions are erroneous. Suppose, now, b and e to be the assumed axis and ellipticity; $b+\delta b$, and $e+\delta e$, the real axis and eccentricity; λ' the calculated latitude of the second point, $\lambda'+\delta\lambda'$ the observed latitude. Then the first calculation being made for a spheroid, we have

$$\text{Measured arc} = b\left(1+\frac{e}{2}-\frac{3e}{2}\,.\cos\overline{\lambda'+\lambda}\,.\,\frac{\sin\overline{\lambda'-\lambda}}{\lambda'-\lambda}\right)\times(\lambda'-\lambda)\sin 1''.$$

And as the same arc corresponds to the observed latitudes on the spheroid really existing we have (omitting $\delta\lambda'$ in $\cos\overline{\lambda'+\lambda}\,.\,\frac{\sin\overline{\lambda'-\lambda}}{\lambda'-\lambda}$, in which it makes no sensible difference)

$$\text{Measured arc} = (b+\delta b)\left\{1+\frac{e+\delta e}{2}\left(1-3\cos\overline{\lambda'+\lambda}\,.\,\frac{\sin\overline{\lambda'-\lambda}}{\lambda'-\lambda}\right)\right\}(\lambda'-\lambda+\delta\lambda')\sin 1''.$$

Taking the difference, and neglecting the products of δb, δe, $\delta\lambda'$,

$$0=\{(\lambda'-\lambda)\delta b+b\,\delta\lambda'\}\,.\left(1+\frac{e}{2}-\frac{3e}{2}\,.\cos\overline{\lambda'+\lambda}\,.\,\frac{\sin\overline{\lambda'-\lambda}}{\lambda'-\lambda}\right)\sin 1''$$
$$+\,b\,(\lambda'-\lambda)\left(\frac{1}{2}-\frac{3}{2}\,.\cos\overline{\lambda'+\lambda}\,.\,\frac{\sin\overline{\lambda'-\lambda}}{\lambda'-\lambda}\right).\,\delta e\,.\sin 1''.$$

Whence

$$0=\frac{d\lambda'}{\lambda'-\lambda}+\frac{db}{b}+\frac{1-3\,.\cos\overline{\lambda'+\lambda}\,.\,\frac{\sin\overline{\lambda'-\lambda}}{\lambda'-\lambda}}{2+e-3e\,.\cos\overline{\lambda'+\lambda}\,.\,\frac{\sin\overline{\lambda'-\lambda}}{\lambda'-\lambda}}.$$

Form of equations of condition.

Or (as e is small)

$$0=\frac{\delta\lambda'}{\lambda'-\lambda}+\frac{\delta b}{b}+\left(\frac{1}{2}-\frac{3}{2}\,.\cos\overline{\lambda'+\lambda}\,.\,\frac{\sin\overline{\lambda'-\lambda}}{\lambda'-\lambda}\right)\delta e.$$

Every measure gives an *equation of condition* of this form; these are to be used in the same manner as similar equations in other astronomical investigations. A similar process can be extended to arcs of longitude.

Deviations from the elliptic form.

Hitherto, in the whole of this section, we have supposed the Earth's form to be a perfect spheroid. We shall now consider the indications which, using the same observations and the same measures, would show the existence of some deviation from that form.

Dissimilarity of Northern and Southern hemispheres.

If the Northern and Southern hemispheres of the Earth were dissimilar, the radii of curvature in corresponding North and South latitudes would be unequal, and therefore the lengths of degrees in corresponding North and South latitudes would not be the same. Conversely, if it is found that the length of a degree in any North latitude is not the same as that in equal South latitude, we must conclude that the Northern and Southern hemispheres are not similar.

Earth's form not a solid of revolution.

If the Earth were not a Solid of revolution, the different meridians would be different curves, and, therefore, at the same latitude, but in different longitudes, the degrees of meridian would be unequal. The parallels, also, would not be circles, and, consequently, different degrees of longitude on the same parallel would have different lengths. An inequality then either in the degrees of latitude or in those of longitude, depending on the difference of longitude, will show that the Earth's form is not one of revolution.

Form generated by the revolution of a curve differing from the ellipse.

But the Earth's form, even though perfectly symmetrical, may be formed by the revolution of some figure differing from the ellipse. The generating curve for instance, as A Q D, fig. 21, may project between A and D above the ellipse which has the same axes. This deviation of form would be thus discovered. It is plain that at A and D the curvature is diminished, or the radius of curvature increased; and at Q the curvature is increased, and the radius of curvature diminished. Consequently, the length of degrees near A, and near D, is greater, and near Q it is less, than in the elliptic spheroid. In the spheroid the degrees at Q are longer than those at D, and shorter than those at A. Consequently, the difference of the length of degrees at Q and D is diminished; and the difference of those at Q and A is increased. The ellipticity (as is easily seen in the formulæ above) is found by dividing the difference of degrees in different latitudes by a coefficient depending only on the latitudes. This process is properly applicable only to an elliptic spheroid; but if we use it for such a curve as A Q D, it is clear that an ellipticity greater than the true value will be found where the difference of degrees is greater than in an ellipse, and less than the true value where the difference is less. Consequently, by comparing two arcs measured at D and Q, and using the elliptic formula, we should get an ellipticity smaller than the truth; by comparing those measured at Q and A we should get a value greater than the truth. Conversely, if the comparison of arcs near the Equator, and arcs in middle latitudes, give a smaller value of the ellipticity than the comparison of arcs in middle latitudes, and arcs near the Pole, we shall be entitled to conclude that the Earth's form projects at middle latitudes beyond the elliptic spheroid which has the same axes. If the difference be of the contrary kind, we may conclude the Earth's form to be more flattened at middle latitudes than the ellipse which has the same axes.

Indicated by the comparison of three meridian arcs.

The same deviation from the elliptic form might also be discovered thus. By a projection at Q above the elliptic form, the degree of parallel passing through Q, would be made greater than in the ellipse at the same latitude. Suppose the latitude of Q to be 45°, and suppose that two meridian arcs were measured of which the middle points were in latitudes 0°, and 45°, respectively. For $\frac{A}{(\lambda'-\lambda)\sin 1''}$ in the equatorial arc put f, and in the other f'; and for $\frac{C}{D\cos L\sin 1''}$ put g. Then the values of the ellipticity found by comparing each of

Or by the comparison of two meridian arcs with an arc of parallel.

Figure of the Earth.

the meridian arcs with the arc of longitude would be as follows:

$$\text{by the Equatorial arc } \frac{2}{5} \cdot \frac{g \cdot f}{b},$$

$$\text{by the other } 2\ \frac{g - f'}{b}.$$

Now g and f are greater than in the ellipse, and f' is less. The ellipticity therefore given by comparing the arc of parallel with the Equatorial arc of meridian, might, or might not, be too great; but that given by comparing it with the other arc would certainly be much too great. That is, a larger value of ellipticity would be found by comparing the arc of parallel with the arc of meridian in latitude 45°, than by comparing it with one measured across the Equator. If then we find, on comparing an arc of parallel nearly in latitude 45° with arcs of meridian near the Equator, and near latitude 45°, and applying the elliptic formulæ, that the first comparison gives a smaller value for the ellipticity than the second, we may conclude that the Earth's surface at latitude 45° is further from the centre than if the form were that of an elliptic spheroid.

Having thus explained the mode of using measures of meridians and parallels for the determination of the Earth's Figure, we shall now proceed to give an account of the principal measures which have been made.

Section 4.—Measures of Arcs of Meridian.

It will not be expected that we should lay before our readers a complete account of all the measures that have been made. Our limits will not allow this; nor is it by any means necessary. It is our object to give such information as will enable any one to understand the calculations of the several arcs, to appreciate their exactness, and to estimate their importance as conducing to our knowledge of the Earth's form. We shall touch lightly on those measures, which though on a large scale, have not been conducted with the extreme care requisite in such delicate operations, but we shall describe fully the methods, and explain accurately the theories of those which have been adopted, almost by general consent, as the only ones proper to determine the Figure of the Earth. For details we must refer to the original accounts.

Of the rough estimations of the Greek Astronomers, and the somewhat less rough measure of the Arabian Caliph, we have given in the first section as full an account as they deserve. The still more accurate measures of Fernel and Norwood have received sufficient attention. As specimens of attempts made before good instruments were invented, or refined theories formed, they are curious; and their results are not so inaccurate as might, at first sight, be expected. But the great principle of triangulation was then unknown; and little reliance can be placed on the measures in which this was not adopted. We shall commence with a general account of the methods followed in those measures in which triangulation has been used.

Meridian Measures

Preparations for measure of base.

The first part in order of calculation (though not always the first in order of time) is the measure of a base. The method which has generally been pursued is something like this. The extremities being chosen, (the requisites of which are, a sufficient distance, as four or five miles on a pretty level plain, and the power of seeing the same two signals, or at least one, at each extremity,) a telescope, mounted like a transit instrument, is placed at one extremity, and an observer, by means of it, is enabled to direct an assistant to fix stakes in a straight horizontal line, or rather in a vertical plane, on the whole length of the base line. These serve as guides in the actual measure. The base is sometimes measured roughly with a common chain, to prevent any serious error of omission in the subsequent measure, and to point out the places at which it is necessary (in some methods) to fix posts for the accurate measure.

Rods used for base-measure.

For this purpose fir-rods were universally employed till the commencement of the English survey. From some experiments made by General Roy, it appeared that they were subject to considerable alterations of length from moisture; they were laid aside, and glass tubes (and ultimately a steel chain) employed. But the reader must not suppose that these alterations had never been observed before, or that the base-measures anterior to this time were affected by the errors which they would occasion. It was usual in the former measures to keep an iron rod of a toise (a little more than a fathom) in length, as the real standard, and to compare it several times a day with the wooden rods with which the work was actually performed. As the length of the rods in general was several times that of the iron toise, brass pins were fixed at distances as nearly as possible equal to the length of the standard, upon which fine dots were made. The comparison was made by means of *beam-compasses*, (a long rod having at one end a fixed point perpendicular to its length, and at the other a point attached to a frame movable along the rod by means of a micrometer-screw.) The beam-compasses being so adjusted by the standard, that the distance between their points was exactly a known length, the fixed point was applied to one of the dots on the wooden rod, and if the movable point would not touch another it was moved by the micrometer-screw till it came in contact, and thus the difference of length was ascertained with great accuracy. This continual comparison was very troublesome, but we apprehend that little has been gained in point of accuracy by the use of the subsequent methods. When this was done, it is plain that the measured length was the same as if it had been effected with the metallic standard; and, consequently, the same corrections for the expansion or contraction of the metal from change of temperature were necessary.

Manner of placing the rods.

Several rods being provided, they were sometimes laid on the ground, but more frequently were supported on trestles. The end of the first was adjusted to the extremity of the base by a plumb-line; the others were in some instances brought in contact; but more frequently they were placed so as to leave a small interval, which was measured by a small graduated tongue or slider attached to one, and which was moved till it touched the next. Sometimes all were placed horizontal by a carpenter's square, or a spirit-level; then, if the ground was not level, it was necessary to suspend a plumb-line from the extremity of one, and to make it pass over a given point of the next. Sometimes they were inclined so as always to bring the ends in contact; then the inclination was measured, and allowance made for it afterwards. One principle was adopted in every instance, (except that of the English chain-measure,) that at least two rods should be in their places when a third was applied. Of the different methods, we cannot say that any one is preferable to the others.

The arc being thus measured, and the reduction for inclination applied, (if the rods were inclined,) and the correction for temperature being also applied, we have the sum of a series of lines similar to the short lines in fig. 22, measured with the standard bar at the standard temperature. Each of these lengths ought now to be reduced to the projection on some surface (the level of the sea has always been chosen) by lines drawn in the direction of Gravity. If r be the Earth's radius or the radius of the surface of the sea, (which is known nearly enough,) h the elevation, the measured lengths must be multiplied by the fraction $\frac{r}{r+h}$, or $1-\frac{h}{r}$, or they must be diminished by the part $\frac{h}{r}$ of the whole. If the surface slopes uniformly, the mean height may be taken; if it is very irregular, it may be divided into several parts. The reduced length $a\,b$, fig. 22, of the base A B, is now found; if the length of the chord be required, it is easily found by subtracting $\frac{A\,B^3}{24\,r^2}$.

Reduction for elevation above the sea.

Signals.

The signals at the principal stations have generally been flagstaffs, poles supported by piles of stones, pyramids of wood, broad plates of wood or metal with a hole through which the sky was visible, or Bengal lights; placed for the purpose on the same spot as the instrument with which the angles were observed. Sometimes advantage has been taken of church spires, windmills, &c., near which the quadrant or theodolite could be placed; a reduction is then necessary, to make the angle such as it would have been if the instrument had been placed exactly on the signal. Thus, in fig. 23, suppose E and F signal stations, from which the signal G has been observed; the instrument cannot be placed at G, but is placed at g; the length Gg, and the angle GgE, GgF, are observed. The real angle E G F is greater than the observed angle EgF by G Fg − G Eg. And $\sin GFg = \frac{Gg}{GF} \sin GgF$, which is easily calculated, as an approximate knowledge of G F is sufficient. Similarly G Eg is calculated. Thus the angle is found which would have been observed at G.

Measure of angles between signals.

The instruments which have been used for measuring the angles are quadrants, theodolites, and repeating-circles. When we consider the various errors to which quadrants are liable, it seems strange that the use of whole circles should not have been sooner introduced. But these evils (like most others) can be evaded if sufficient labour is bestowed upon them. The principal errors to which they are liable are, inequality in the parts of the graduation; and eccentricity, by which a further apparent inequality is created, and the proportion which the whole arc bears to the circumference is vitiated. The last defect was discovered and measured by placing the quadrant in a situation where the horizon was clear, and observing the apparent angular distance from an object A to another B, from B to C, and so on to A again, when the sum of all ought to equal 360°. The first was found by measuring the same angle on different parts of the quadrant, or by some equivalent method. When these points were attended to, we doubt whether the defects peculiar to the quadrant produce errors of any importance. The English theodolite and the French repeating-circle are undoubtedly superior, chiefly because the art of making instruments is improved. In respect of accuracy we should be inclined to prefer the theodolite; but the portability of the repeating-circle is a most valuable quality, especially in the survey of a mountainous country.

Verification quadrant.

Angles duced t horizon angles.

With the quadrant and the repeating-circle, the angle contained between two signals was observed; with the theodolite, the horizontal angle was observed, and not the angle actually subtended by the signals, except both were in the horizon. In some of the earlier surveys, the true angles, unreduced, were used, and the length of the opposite sides was calculated, and this process was continued through the whole chain of triangles. For the subsequent calculations, however, it was necessary to reduce them to horizontal angles. Here it is plain that the sides of the triangles were the actual lengths from one station to another, measured in straight lines, which would be in general inclined to the horizon. But in most instances the observed angles have been reduced to horizontal angles by the approximate method given in TRIGONOMETRY, Art. 181.; sometimes by rigorous calculations of the triangle, whose angles are at the zenith, and the two signals. Then the triangles were generally calculated as plane ones. The accuracy of the English survey made the difference between plane and spherical triangles sensible; and the English reduced the spherical triangle to a plane one, whose sides were the chords joining the stations, or rather the projections of the stations on the spheroid, whose surface is the level of the sea, by the formula in TRIGONOMETRY, Art. 182. The French calculated the triangles by Legendre's formula, given in TRIGONOMETRY, Art. 183. The first of these methods has been used in the whole of the English survey, and in that of India; the second has commonly been employed on the Continent since the year 1780. The spherical excess, it must be observed, is the same on a spheroid as on a sphere, where the latitudes and difference of longitudes of the stations are the same; of this we shall give a demonstration when we treat of the determination of differences of longitude.

Calcul of trian

Deter tion of muth o signal.

The next step is, to determine the direction of one of the sides with regard to the meridian. The general principle is this. The error of a clock or chronometer with respect either to solar or to sidereal time, may be found by means of a transit-instrument, or by observations of equal altitudes, or by absolute altitudes if the latitude of the place be well known. It is easy to calculate the azimuth of a star or the Sun at any given time; and, consequently, (the clock-error being known,) at any given clock-time. And if the star or sun be used when near the horizon, the angle made with another object will not be much affected by the uncertainty of refraction. At a signal station, therefore, the angle made by another signal with some celestial body near the horizon is observed, and the time noted; by applying the clock-error the true time is found; the azimuth at the instant is calculated; and by adding or subtracting the observed angle the azimuth of the station is found. The Sun, at rising or setting, or some circumpolar star, as Capella, passing the meridian below the Pole, has generally been used. The azimuth of Polaris, at its extreme digressions, has been observed with a theodolite; or the distance of Polaris from a signal, when apparently nearest to it or furthest from it.

with a repeating-circle. The former method requires extremely good adjustment of the theodolite; the latter, a very precise knowledge of the latitude and the refraction. The following method seems preferable where it is practicable. A temporary mark is fixed as nearly as possible in the meridian. A transit-instrument is adjusted upon it, and the transits of stars at different Polar distances are observed. The deviation of the transit-instrument, or the azimuth of the mark, can be determined thus with extreme accuracy. By means of the theodolite or repeating-circle, the angle between this mark and one of the signals can be observed, and thus its azimuth can be found. The Baron de Zach has suggested the observation of what he calls circum-meridian observations of the Sun. When the Sun is near the meridian his motion in azimuth is nearly uniform, and can easily be calculated. Repeated observations can be made; and the time being noted, his azimuth can be calculated more easily than when he is in any other part of his course. It is necessary that the clock-error be determined by transits of the Sun; for the Solar Tables (Delambre's or Carlini's) are not sufficiently exact to give his azimuth at a time determined by transits of stars, and the observation of equal altitudes is not sufficiently accurate. If night-signals can be used, the observation of a circumpolar star under the Pole would possess the same advantages without the same liabilities to error.

Calculation of arc of meridian.

We are now able to calculate the distance of the parallels which pass through the extreme stations of the chain of triangles. This, in the light in which we have considered these measures, is the sole object of the survey; but in point of fact nearly all the measures of arcs have been parts of surveys for mapping the country. Perhaps it is owing to this circumstance that the method of parallels and perpendiculars has been so much used. In the first extensive survey of France (of which Picard's arc was the beginning, and the arc measured and remeasured by J. Cassini and Cassini de Thury a continuation) an imaginary meridian line was drawn through Paris, and lines perpendicular to it were drawn across the kingdom at intervals of 60,000 toises, and chains of triangles were carried as nearly as possible along them; which were the foundation of the grand survey of France. In the English survey, meridian lines were traced through eight of the principal stations; and though the course of the triangles was not particularly directed by them, the places of all the stations were referred to them.

Method of parallels and perpendiculars.

It is plain that no method of determining the situation of a place could be more convenient than to give the distance from the fundamental point along a given line to the foot of the perpendicular passing through the point in question, and to give the length of that perpendicular; it is in fact the same as giving the rectangular coordinates x and y of the point. It is also convenient for the meridian measure. The only point of importance to be attended to is, that the perpendiculars be not so long that the difference between the spherical length of the sides, and their length when projected on the tangent plane, (or rather the tangent cylinder, which touches the sphere in the line to which the points are referred) become sensible. This was secured in the mapping surveys by using several lines of reference instead of one; and in the chain of triangles used for a meridian measure there is no fear that the perpendiculars will be too long.

Distance of feet of perpendiculars calculated.

Now let fig. 24 represent such a chain of triangles with the perpendiculars drawn from the stations upon the meridian passing through A one extremity. The length of A B, and its azimuth, (or the angle B A b,) are known, and therefore, A b and b B can be found; and similarly A c and c C. Through B draw g B h parallel to b A. The angle A B h is equal to B A b, and C B A and C B D have been observed; hence D B g = A B h + C B A + C B D − 180° is known. Also D B is known; and hence D g and g B can be calculated. Adding D g to g d or B b, which has been calculated, we have D d; and adding g B to b A we have A d. These can also be determined from the position of C by the length and direction of the line C D; and if the two results differed it would be proper to take the mean. Then the meridian distance and perpendicular for F, would be found from those at C and D; and so on to the end. It must be observed that g B h is not the meridian passing through B, and therefore D B g is not the azimuth of D as seen from B; it differs from it by an angle termed *the convergence of meridians*, of which we shall speak hereafter. We may also remark that there is no inconsistency in taking into account the spherical excess, while we neglect here the difference between the lengths of lines on a sphere or spheroid, and the corresponding lines on a cylinder; the former varies, *cæteris paribus*, as the square of the sides, and the latter as the cube, and therefore, when the triangles are very small in comparison with the Earth's radius, the latter is smaller in proportion to the quantities retained than the former.

Difference between perpendicular and small circle.

Now let F be the last of the stations. The distance A f is not the distance between the parallels passing through A and F. For produce A f to P the Pole of the Earth, and describe a small circle, F f', of which P is the centre. Then A f' is the real distance between the parallels, and $f f'$ must be subtracted from the ascertained length A f. This quantity may be calculated in the following manner. F f is part of a great circle, (since it is produced in a vertical plane,) F f' is part of a parallel. In fig. 25, we have represented the chain of triangles on the surface of the sphere, or spheroid; with the plane of the great circle F f G M, and that of the small circle F f' G N, intersecting in the straight line F m G. Fig. 26 represents the plane of the circle P A; m is the point at which the radius of the great circle and the small circle intersect. Now $f f' = m f . \tan f m f' = m f . \tan f K e = m f .$ tan latitude of f; or $= m f .$ tan latitude of F (the difference being very small.) But $m f$ is evidently the versed sine of the arc of F f to radius K f, and therefore

$$= \frac{\overline{\mathrm{F}f}|^2}{\text{Earth's diameter}};$$

consequently,

$$f f' = \frac{\overline{\mathrm{F}f}|^2 . \text{ tan lat. of F}}{\text{Earth's diameter}}.$$

We believe that this would be the easiest way of making the calculation. But it has generally been done thus. From the approximate knowledge of the Earth's dimensions find the arc of a great circle in degrees and minutes corresponding to the length F f. Consider P F f as a right-angled spherical triangle, of which the side P f will be determined by this formula,

$$\cos \mathrm{P}f = \frac{\cos \mathrm{PF}}{\cos \mathrm{F}f} \text{ (Trigonometry, Art. 105.)}$$

Take the difference between P F and Pf in degrees, and from the assumed radius of the Earth convert it into fathoms. This method appears troublesome, it requires logarithms of 7 places; that above would not require logarithms of more than 4 places.

Convergence of meridians.

We may now easily see what is meant by the convergence of meridians. In fig 24, or 25, join P F by an arc of great circle. Then P F is not perpendicular to Ff, and therefore in fig. 24 it is not parallel to Pf. The angle is easily found by solution of the same spherical triangle, P Ff, thus, $\cos \mathrm{PF}f = \dfrac{\tan \mathrm{F}f}{\tan \mathrm{PF}}$. (Trigonometry, Art. 109.) If now (as frequently happens) the azimuth of B had been observed at A, and that of E at F, and it was desired to know how nearly one coincided with the result calculated from the other, the process to be used would be this. Since fF E is known, (by the antecedent calculations,) and A Ff is known, (by the solution of the spherical triangle just given,) their sum P F E is known; and this is the angle to be compared with the observed azimuth.

Delambre's method of calculating arcs of meridian.

The method invented by Delambre, and used in the measure of the French arc commenced in 1792, and in most of the continental surveys since that time, is certainly more elegant, and, perhaps, in some respects, more convenient than that which we have described. The triangles were calculated as spherical triangles, and therefore the spherical excess was computed for no other purpose than to discover the sum of the errors in the observation of the angles. When the side a, and the two adjacent angles B, C, of a triangle are known, and its area roughly calculated, from which the spherical excess x is found, then $\mathrm{A} = 180 + x - \mathrm{B} - \mathrm{C}$, and

$$\mathrm{Sin}\, b = \frac{\mathrm{Sin}\, a \,.\, \sin \mathrm{B}}{\sin \mathrm{A}}, \quad \mathrm{Sin}\, c = \frac{\mathrm{Sin}\, a \,.\, \sin \mathrm{B}}{\sin \mathrm{A}},$$

where by Sin a we mean the sine in the circle whose radius $= \mathrm{R} =$ Earth's radius. Now $\mathrm{Sin}\, a = a \dfrac{\mathrm{Sin}\, a}{a}$; and a is a quantity whose logarithm is found easily from the common tables, and $\log \dfrac{\mathrm{Sin}\, a}{a}$ is a quantity that varies very slowly, and can be taken from a very small table constructed for the purpose. Now the general problem is this. Given the Earth's dimensions to tolerable accuracy, the length of A B, fig. 27, the angle P A B, and the latitude of A, to find the difference of latitudes of A and B, the distance of the parallels, the difference of longitudes, and the angle P B A. Draw A Q the normal at A, B S that at B. As the Earth's form is not spherical, these normals will not (in general) meet the axis P S in the same point. Join B Q, A S; and suppose that a sphere described from the centre Q with radius 1, cuts the lines Q P, Q A, Q B, in p, a, b. The angle at P, or the difference of longitudes will be the same as the angle at p; that observed at A will be the same as that at a, since each is the inclination of the planes A Q P, A Q B; but the angle observed at B will not be the same as the angle $p\,b\,a$. For suppose the angle measured with a theodolite; its axis must be vertical; that is, it must be in the direction B S; consequently the angle which it measures is the angle made by the planes B S A, B S P; whereas $p\,b\,a$ is the angle made by the planes B Q A, B Q P. We have now to inquire, Are the planes B S A, B Q A, equally inclined to the plane B P Q S? In general they are not; but we can investigate their difference thus. Draw A a' perpendicular from A on the meridian plane P B; and from a' draw $a's'$, $a'q'$, perpendicular to B S, B Q. This is more clearly represented in fig. 28. Then the plane A a' s' is perpendicular to B S, and therefore the tangent of the angle observed at B is $-\dfrac{\mathrm{A}a'}{a's'}$. Similarly the tangent of the angle $p\,b\,a$ is $-\dfrac{\mathrm{A}a'}{a'q'}$. Hence $\tan p\,b\,a = \tan$ angle at $\mathrm{B} \times \dfrac{a's'}{a'q'}$. These will be absolutely equal when $a'q' = a's'$; or when the elevation of A actually observed at B is equal to the depression which would be observed if the axis of the theodolite were in the line B Q; that is, if A be very near the horizon of B. The error of the assumption, that $p\,b\,a =$ the angle observed at B, depends therefore entirely on this circumstance, that a perpendicular at A, when observed at B, does not appear perpendicular. This, however, is not discoverable by the senses when assisted by the best instrument; and, therefore, we may at once assume that $p\,b\,a$ is equal to the azimuth of A as observed at B. Now, in the spherical triangle $b\,a\,p$, we have given $p\,a =$ colatitude of A; $b\,a\,p =$ observed azimuth; $a\,b = \dfrac{\mathrm{A\,B}}{\mathrm{A\,Q}}$, whose determination therefore requires a knowledge of A Q as well as of A B (if the form be assumed to be elliptical A Q = P V, in fig. 10,

Azimuth at second station may be calculated as on a sphere.

$$= \frac{\mathrm{C\,N}}{\mathrm{R\,N}} \,.\, \mathrm{P\,R} = \frac{a^2}{b^2} \,.\, \mathrm{P\,R}$$

$$= \frac{a^2}{\sqrt{a^2 \cos^2 \lambda + b^2 \sin^2 \lambda}} = b\,(1 + 2\,e - e \cos^2 \lambda),$$

if we neglect powers of the ellipticity) and a small table of the value of log A Q at different latitudes must be made: it varies very slowly. Then solving the triangle as a spherical triangle, for which the method in Trigonometry, Art. 186. was generally used by Delambre, and is shorter than the accurate computation, we have the azimuth $\mathrm{PBA} = p\,b\,a$; and the distance $a\,b''$ of the parallels passing through a and b; whence the distance $\mathrm{A}\,b' = \mathrm{A\,Q} \times a\,b''$ is found. For a survey of meridian lines these two determinations (the azimuth of A as seen from B, and the distance in linear measure between their parallels) are all that are necessary; but as it is always desirable, and in mapping necessary, to determine the latitudes and longitudes of the stations, on assumed dimensions of the Earth, the following must also be calculated. The difference of longitudes B P A, which is the same as $b\,p\,a$; and the difference of latitudes, which is obtained by dividing the distance between the parallels by the radius of curvature of the meridian at the middle point, or (in the ellipse)

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by

$$\frac{a^2 b^2}{\left(b^2 \sin^2 \dfrac{\lambda + \lambda'}{2} + a^2 \cos^2 \dfrac{\lambda + \lambda'}{2}\right)}$$

or

$$b\left(1 - e + 3\,e \sin^2 \frac{\lambda + \lambda'}{2}\right).$$

We will remark here, once for all, that the theory of the shortest lines that can be traced on an ellipsoid between two points has no application to the sides of Geodetic triangles, as some writers have supposed. The lines which determine the azimuths, &c. are the lines which represent the rays of light passing from one signal to another; and light does not move in the shortest curves that can be traced on ellipsoids, but in straight lines. In consequence of this, (as may be observed in the theory just given,) the truth or falsehood of some of our propositions will depend on the relative elevation of the signals. And in all the more delicate parts of the theory, we must consider the signals as being elevated above the curved surface. Thus Delambre treated the subject; and thus it had been treated long before in some masterly Papers by Dalby, in the *Phil. Trans.* for 1791 and 1795, which are transcribed in the first volume of the *Account of the Trigonometrical Survey*. If we chose to take into account the terrestrial refraction, and to suppose that refraction always bends the light towards such a *shortest line*, we ought to correct our results by about $\frac{1}{12}$th of the difference between them and those obtained by the theory that we have rejected; but such a refinement would be ridiculous.

Theory of shortest lines does not apply in Geodetic theorems.

Determination of difference of latitudes by observation.

We have here given every thing necessary for determining the distance between the parallels passing through the extreme stations of the chain of triangles; and the Geodetic part is completed. We now come to the Astronomical determination of the latitudes at the extremities; a determination on the accuracy of which the exactness of the whole operation depends, and whose difficulties far exceed all the difficulties of the other determinations

Small [illegible] in the [illegible] [illegible] is of no consequence.

From the description of the general principle which we have given in the Ist section, and from the formulæ in the IIId section, it will appear that if the difference of latitudes of the extreme stations be accurately determined, the radius of curvature at the middle point will be known; and, if a small error be committed in fixing on the absolute latitudes, (from which the latitude of the middle point is found,) it will have no sensible effect on the resulting dimensions of the Earth. For if we take the expression which gives the ellipticity by comparison of two measured arcs,

$$e = \frac{\dfrac{A}{(\lambda' - \lambda) \sin 1''} - \dfrac{B}{(\mu' - \mu) \sin 1''}}{3\, b \left(\sin^2 \dfrac{\lambda' + \lambda}{2} - \sin^2 \dfrac{\mu' + \mu}{2} \right)},$$

in which the numerator is certainly small, and the denominator is not generally small, it is evident that the value of the denominator will not be much altered by a small alteration in $\frac{\lambda' + \lambda}{2}$; for instance, if

$$\frac{\mu' + \mu}{2} = 0, \text{ and } \frac{\lambda' + \lambda}{2} = 45^\circ,$$

an error of 1 in $\frac{l' + l}{2}$ would only alter the denominator from $3\, b \sin^2 45^\circ$ to $3\, b \sin^2 44^\circ 59'$. But an error in $\lambda' - \lambda$ will produce a very serious effect in the numerator; as if $\lambda' - \lambda = 1^\circ$, an error of $1'$ will alter $\frac{A}{(\lambda' - \lambda) \sin 1''}$ from $\frac{A}{3600 \sin 1''}$ to $\frac{A}{3540 \sin 1''}$, or will increase it by $\frac{1}{60}$th part; and if $\frac{A}{(\lambda' - \lambda) \sin 1''}$ exceeds $\frac{B}{(\mu' - \mu) \sin 1''}$ by only $\frac{1}{360}$th part, it will from the effects of the error exceed it by $\frac{7}{360}$th part, or the resulting ellipticity will be seven times as great as before. In estimating, then, the accuracy of the observations for determining the latitudes, we have no need to inquire into the exactness of the determination of the absolute latitudes, but only into that of the difference of latitudes.

An error in the difference of latitudes is very important.

General description of the zenith-sector.

The instrument with which the difference was commonly determined in the surveys previous to 1787 is the zenith-sector. With this instrument the zenith-distance of stars that pass near the zenith can be ascertained with great accuracy. At the two extremities of an arc the same stars were observed at their meridian passage; and, without any knowledge of their declination, the difference of their zenith-distances was found; which is equal to the difference of the Astronomical latitudes. As much of the credit of several of the measures depends on the capability of this instrument, we shall give a general description of it, and of the method of using it. In fig. 29, A B is a bar of iron with a cross-piece C D, the whole in one piece. The top, A, is formed in such a way that the instrument can be turned half round in azimuth when suspended at the top, and that the bottom can be moved freely in the directions D C, or C D. It might be made as represented in the figure; or it might move on a hinge for its ordinary motion, and in a swivel for its azimuthal motion. The bracket, or other support, E, on which it rests, is attached to some firm part of the building. To the bar, A B, is firmly attached a telescope, F G. At a point, *a*, near A, is attached a plumb-line, *a* H; sometimes it is fastened at a point of attachment which is movable, in order that, by moving the point of suspension, the plumb-line may be made to pass over a fine dot at *a*. The limb, CD, is graduated, sometimes on a circular arc, of which *a* is the centre, and sometimes on a straight line. L D is a screw passing through a block strongly connected with the floor, and acting with its point against the end D of the piece C D; and M N O is a string and weight pressing the sector against the point of the screw.* The method of using it is this. By transits, or equal altitudes, a clock is regulated to solar or sidereal time; and then, the time at which celestial bodies pass the meridian being known, the meridian line is easily found with tolerable correctness. A cord is stretched across the room, and this serves well enough (as great accuracy is not necessary) to direct the astronomer in fixing guides which will compel the sector to move in the direction of the meridian. When a star is to be observed, the screw L D is turned till the plumb-line falls exactly on some point, K, of the graduation, such that the telescope is very nearly directed to the star; and the number of

Method of using the zenith-sector.

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* It will readily be understood that this description, and the figure belonging to it, are intended to illustrate only the general principle of this instrument, and that most of the details, which can be supplied without difficulty by those conversant with instruments, are wholly omitted. For instance, the screw generally acts in a movable piece which is clamped in any convenient position, so as to diminish very much the range of the screw. The construction represented in the figure is probably the worst form in which the instrument has ever been used.

turns and fractions of a turn (as shown by a scale and divided head, not represented in the figure) are read. When the star enters the field of view, the screw is again turned, till it appears to glide exactly along the wire fixed in the focus of the eye-glass, and the turns and parts of a turn again read. The motion of the screw being thus ascertained, its value in degrees and minutes is to be added to the value of the graduation, K, and thus the apparent zenith-distance of the star is found.

Reversion necessary.

Now, it is evident that this is not the true zenith-distance, except the place of the division 0, be quite correct. It is impossible to insure this; but it is easy to see, that if the instrument be turned half round in azimuth, and the same observation made, the apparent zenith-distance will be just as much greater than the true, as in the former observation it was less. The mean of the two determinations will be the true zenith-distance.

For accuracy it is indispensably necessary, that the telescope F G preserve the same position with regard to the frame in the observations before and after reversion. In the best sectors this has been secured by omitting the bar, A B, entirely, and attaching the limb, C D, to the tube of the telescope. In several, instead of turning the screw, L D, to bring the wire upon the star, the wire is moved by a micrometer-screw within the telescope. And in some, a graduated scale slides in a groove on the arm, C D, and when the instrument has been moved till the star glides along the middle wire, the scale is moved by a micrometer-screw till a division is brought under the plumb-line, and the reading of the micrometer-head is then registered.

Advantages of this instrument.

We request the reader to notice the construction of this instrument, because all the discordances between ancient and modern measures on the same line, appear to be owing to the difference of determinations with the zenith-sector and the repeating-circle. We confess that to us it appears impossible, when the instrument is made with any reasonable care, that the error in its results can be at all serious. The stars observed are in a part of the heavens where the tremor and dancing, which generally affect stars in other positions, are seldom seen; there is no uncertainty about the effects of refraction; the telescope and the whole instrument are not subject to flexure; the variation of temperature produces no sensible effect. We may be excused for reminding the reader, that not only the existence but the magnitude of aberration and nutation were discovered by means of a zenith-sector, and that subsequent observations have added little to the accuracy of the determination.

History of the repeating-circle.

The repeating-circle was invented late in the last century, and was first introduced to the notice of the scientific world by its employment in the French part of the survey for connecting the Observatories of Greenwich and Paris. It was again used in the measure of the arc from Dunkirk to Barcelona, conducted by Delambre and Mechain. From this time, it attained among the French a degree of popularity which can hardly be imagined. The minds of Philosophers, not less than those of Politicians, seem at that period to have been distracted with the idea of obtaining every thing desirable by the application of one sweeping principle. They imagined that the effects of errors of division and errors of observation might be entirely destroyed by repetition, and that no new error would be introduced in their place.[*] And from merely reading the French Works on Astronomy, or almost any other Science, published early in the present century, one might almost imagine that it was impossible to make an Astronomical or Optical observation without a repeating-circle. This instrument, however, was never much used by English observers. This has been remarked by M. Littrow, (in Zach's *Correspondance Astronomique,*) with the commentary, "the English are a practical nation;" which we believe to be the true explanation.

Discor ance of tudes of celona Montjo

One of the first observations which shook the credit of the repeating-circle occurred in the course of the French survey of 1792. In consequence of the breaking out of a war between France and Spain, Mechain, who undertook the survey of the Southern part of the chain, was detained in Spain. He had before observed the latitude of Fort Montjouy, about a mile from Barcelona, and he now wished to repeat the observations; but as he was not allowed to enter the fort, he observed the latitude of Barcelona, and connected it by a small triangulation with Montjouy. The latitude of Montjouy, thus obtained, differed more than 3″ from that found by observation at the place. The chagrin which he felt after attempting in vain to reconcile these observations, undoubtedly contributed to accelerate his death. It was not till the nature of the instrument was better understood that Astronomers had it in their power to explain this apparent inconsistency.

Const error c peatin cles.

It is now universally acknowledged, that all repeating-circles are liable to an error which cannot be removed by any number of repetitions, and which, on that account, is called the constant error: "*constante toutefois jusqu'à un certain point: car il suffit souvent de transporter l'instrument d'un lieu dans un autre, ou de le démonter, pour produire un changement dans le rapport matériel des pièces, et par suite une variation dans la quantité de l'erreur.*" We cite this passage from an interesting Memoir by M. Nicollet on the discordances above mentioned, in the Additions to the *Conn. des Temps*, for 1831. It contains nearly all that is known upon the subject;[†] for the causes of the error are still in obscurity. We beg to refer the reader who wishes to inquire more accurately into the nature of the repeating-circle, to a Paper by Mr. Troughton in the Ist volume of the *Memoirs of the Astronomical Society.*

Prob meth obvia effect

The only mode of observation which appears to be a probable, but not certain, method of removing the error is, if the latitude of a place is the result sought, to observe the zenith-distances of stars passing the meridian at nearly equal distances on both sides of the zenith; the mean of the results will probably be near the truth.

To make this more intelligible we shall give a short

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[*] It is said to have been the opinion of a celebrated French Mathematician engaged in the survey of 1787, that it was no longer necessary to bestow any care on making the triangles well-conditioned, as all possibility of error in the angles would be removed by the use of the repeating-circle.

[†] In the *Exposé des travaux relatifs à la reconnaissance hydrographique des côtes occidentales de France*, p. 86, M. Daussy thinks, that the constant error in observing horizontal angles is proportional to the angle. In some cases, however, he admits that the observed angles could not be corrected by this hypothesis. The Baron de Zach (*Correspondance*, vol. ii.) mentions a repeating-circle with which the observed angles decreased continually; and facetiously insinuates, that if he had continued the repetition of observations of a right angle for several years he should have reduced it to nothing.

account of the mode of observing with this instrument. Figs. 30 and 31 represent it as used for finding the angular distance of two objects, A and B, in any positions, (the stand, &c., being omitted for clearness.) Both telescopes are movable on the circle, which is graduated on one side only; and the telescope on that side carries one, or (more generally) four verniers. Suppose now in fig. 30, C, the telescope on the graduated side, is directed to the object B, and D, the other telescope, is pointed to A; in this state the vernier or verniers of C are read off. Then the whole circle is turned in its plane till the telescope D (which remains clamped to it) is directed on B; and the telescope C is then released and turned, while the circle remains fixed, till it is pointed to A. It is plain that C has been turned through an angle equal to twice the angle sought. Now the whole circle must be turned again till C points to B, and D must be turned till it points to A. Then the circle must be turned again till D points to B, and C must be turned till it points to A; when C will have been turned through four times the arc; and by a repetition of this process the arc can be multiplied any even number of times. The general rule is, to move the circle only in one direction, and the telescopes only in the opposite direction. Two observers are generally necessary. It is necessary to read the verniers only at the beginning and the end, except it is wished to ascertain whether the angles are generally equal.

For observing zenith-distances of stars, advantage is taken of a spirit-level attached to the telescope D, and the telescope C only is used. The verniers of C are read, and then the whole circle is turned in its plane till C is pointed to the star S; and D is moved on the circle till the bubble of the level E is either in the middle, or is so near it, that by the divisions of the level-scales the error can be accurately estimated. Then the instrument is turned half round on its vertical axis, so that, in fig. 33, the face presented to the reader is the ungraduated face; and (if necessary) the circle is moved till the level-bubble is in the same position as before, or else the error is noted Then leaving the circle and D fixed, C is released and again pointed on the star; after which it is necessary to look to the adjustment of the level. C has now described an angle equal to twice the zenith-distance. This (as before) can be repeated any number of times; the motion of the star in the mean time must be calculated from theory. The correctness of the whole depends on the goodness of the level. If the bubble is kept always at the middle, two observers are necessary, one to look through the telescope, and the other to attend to the level. If the level-scales are read every time, a single observer is sufficient. We prefer this mode, not only as requiring fewer persons, but also as being more accurate.

Stars near the zenith cannot be observed with it.

One circumstance which limits the use of the repeating-circle is this. It is impossible to place the plane of the circle perfectly vertical. The error of verticality in most of the repeating-circles which we have seen* cannot be easily ascertained, (except by observing a star, alternately by direct vision and by reflection from mercury, and marking the time and azimuth.) Suppose, now, in fig. 34, Z is the zenith, S the star, T S the great circle representing the plane in which the circle and its telescope move when the telescope is pointed to S. On reversing the instrument, T′ S is the position of the plane. From Z draw Z T, Z T′, perpendicular to T S, T′ S. T and T′ are the highest points of the circle in the two positions; and, consequently, T′, or rather the point corresponding to it in the circle, is the same as T in the other position. The telescope, therefore, has been moved through S T + T′ S, or 2 S T; and half of this, or S T, is the estimated zenith-distance. To find how much this differs from the true zenith-distance, since $\cos TS = \frac{\cos ZS}{\cos ZT'}$, we have

$$\frac{\cos TS - \cos ZS}{\cos TS + \cos ZS} = \frac{1 - \cos ZT}{1 + \cos ZT},$$

or

$$\tan\frac{TS + ZS}{2} \cdot \tan\frac{ZS - TS}{2} = \tan^2\frac{ZT}{2};$$

or

$$\tan\frac{ZS - TS}{2} = \cot ZS \cdot \tan^2\frac{ZT}{2}$$

nearly. If Z S is small, this expression may become considerable. It is necessary, therefore, to avoid observing stars near the zenith, that is in the part of the heavens most favourable for observation.

The telescopes of the repeating-circle very small.

The smallness of the telescopes attached to the repeating-circles diminishes very much the confidence which we might else be disposed to place in them. The largest that we have seen is only 24 inches long. We apprehend that the long telescopes of the zenith-sectors made before the achromatic object-glass was invented, would give a better image of a star. The telescopes attached to the repeating-circle used by Delambre* would not separate the double star ζ Ursæ Majoris; these two stars are distant 14″ or 15″. With such a telescope, the *minimum visibile* is of course not very small. "However an instrument may be constructed, or in whatever manner it may be used, I have no faith that it can give results nearer the truth than a quantity that is visible in the telescope." This opinion we quote from Mr. Troughton's Paper before cited; and we subscribe to it most heartily.

Magnitude of the constant error.

We know not how far† the flexure of the telescopes and the defects of the level are found to introduce errors in the observations of zenith-distances from which observations of horizontal angles are free; but we

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[*] In some of Reichenbach's repeating-circles provision is made for the application and reversion of a cross-level.

[*] We copy this statement from the Memoir of M. Nicollet, *Conn. des Temps*, 1831, *Additions*. M. Nicollet has also attempted to prove that the telescope attached to Mechain's circle was unable to separate this star. This circle is now preserved in the Observatory at Milan, where (through the kindness of MM. Cesaris and Carlini) we lately had an opportunity of examining it, and of trying the telescope upon the star in question. It effects the separation perfectly well. We have since found in an anonymous Memoir of great ability inserted in the *Philosophical Magazine* for March 1829, that Mechain himself had with this telescope observed the star to be double, and had published this observation in the *Monatliche Correspondenz* of Zach. This circle (made by Lenoir) appeared to us to be of very inferior workmanship.

[†] It is the practice of the ablest modern observers with the repeating-circle to determine the flexure of the telescope by observing the angular distance (through the zenith) between two opposite marks in the same straight line with the centre of the instrument, or between the wires of two collimating telescopes, which have been adjusted one on the other. The observed distance will be less than 180° by twice the effect of flexure. It is found in general that the flexure produces an error of several seconds.

should expect that such additional errors exist, and that their magnitude is sensible. Now to give an idea of the amount of errors in observations of horizontal angles, we take the first triangle in the *Opèrations Gèodèsiques et Astronomiques en Piémont et Savoie,* of which the angles were observed by a company of Piemontese officers, and by another company of Austrian officers.

Stations.	Number of Series.	Angles found by the Piemontese.	Number of Series.	Angles found by the Austrians.
Trélod	6	81° 51′ 57″.64	2	81° 51′ 52″.13
Granier ...	8	55 26 42 .22	4	55 26 51 .42
Colombier..	6	42 41 22 .70	3	42 41 20 .99

Here between two values of the angle observed on Mont Granier, one of which is the mean of 80 observations, and the other the mean of 48, we find a difference of more than 9″. A serious error, therefore, exists, which repetition has not been able to remove. But the fact is that the repetition was useless; for the results of the different series agree extremely well. The smallest of the Piemontese results is 55° 26′ 40″.0, and the greatest 55° 26′ 44″.5; the smallest of the Austrian is 55° 26′ 50″.0, and the greatest 55° 26′ 52″. What kind of *constant error* existed in these instruments we can hardly imagine, since in the other angles the difference is of the opposite kind. It is true that this is (as far as we have examined) the worst of the triangles; it is true also that these instruments were not repeating-circles of the usual construction, but repeating-theodolites of only eight inches diameter. But the points which we wish to impress on the reader remain, that repeating instruments are subject to an error which cannot be removed by any number of repetitions, and that the amount of this error is such as to make their results unfit to be put in competition with those of a good zenith-sector. Judging from the agreement of the observations with the same instrument in the instance given above, we apprehend that the smallness of the instruments has had no effect on the discordance of the results.

We have treated at length on the relative value of the zenith-sector and the repeating-circle, because in some instances we shall find different amplitudes assigned to the same arc, according as it has been observed with one or other of these instruments, and because some arcs which have been absolutely rejected by writers on the Figure of the Earth will appear, when the nature of the instruments is examined, to be nearly as trustworthy as those which they have retained. It has been so much the fashion for some years (chiefly among French writers) to extol the repeating-circle, that we know no Work in which the relative merits of the two instruments are stated, to which we could refer the reader.

We shall now mention individually some of the principal measures.

Methods pursued in J. Cassini's measure.

In J. Cassini's measure, the bases were measured with wooden rods of 4 toises each. The angles were observed with a quadrant of 39 inches, and an octant of 36 inches radius. For the azimuth, the clock-errors were determined by equal altitudes, and transits of Capella below the Pole were observed. Some of the azimuths, however, were determined by observation of the Sun at rising and setting. The zenith-distances of stars were observed with a sector of much greater arc than that which we have described above. We think it unnecessary to allude further to this measure, as it gave no result which is of any use at the present day.

Mendi Measu

Methods used in Peruvia measur

In the Peruvian arc, the base was measured with greater care than had before been bestowed on that operation, but with less than would now satisfy Astronomers. The standard measure of France was an iron toise preserved in the Châtelet; but it was so rough that a new standard was necessary; and in fact that used in this measure, and called from that circumstance *the toise of Peru* has always been considered as the real standard. Wooden rods were used for the actual measure, and these were compared with the iron toise every day. Two at least were always in their places while the third was moved; they were always kept in a horizontal position. It does not appear that the thermometer was observed during the measure, but the observers compared the temperature by their bodily sensations with that at other seasons, which had been ascertained by the thermometer; and on this rough estimation, the allowance for the expansion was founded. The temperature to which the measure was reduced was 13° of Reaumur, or 61¼° of Fahrenheit.

Expa of sta ascert

The expansion of the iron toise for 1° of temperature was found in the following elegant manner. The toise was mounted on knife edges so as to vibrate like a pendulum, and another bar was similarly mounted so as to be synchronous with it at a given temperature. The air in the place containing the toise was heated, in consequence of which the toise lengthened, and, therefore, vibrated more slowly than the other pendulum; by observing the number of vibrations which elapsed before its vibrations coincided with those of the pendulum, the alteration of time of oscillation, and consequently the alteration of length, was found; it was ·0117 line for 1° of Reaumur. The length of the base was 6274 toises, 3 inches, and 2 lines; this was obtained by two measures which differed only 3 inches, one party beginning at one end, and at the same time another party at the other end. The South end of the base was 126 toises higher than the North; the base, and in fact the whole measure, was corrected so as to refer it to the level of the lowest extremity of the base. The number of principal triangles was 33. The signals were heaps of stones, pyramids of wood, or tents; the angles were observed with quadrants of three feet radius. The triangles were first calculated without any reduction of the observed angles to horizontal angles, and thus the length of the base of verification appeared to be 5260.03 toises; its measured length was 5258.95. The angles were then reduced to horizontal angles; as the apparent elevation of one signal from another was sometimes 6°, this was done not by an approximate formula, but by accurate computation of the spherical triangle. Then the triangles were again calculated, and the positions of the projections of the signals on the level of the lowest end of the base found by the method of parallels and perpendiculars. The azimuths were determined by observations of the Sun near the horizon; there were in all about 20 observations. The general direction of the chain of triangles made an angle of about 14° with the meridian, extending from North-East to South-West. It seems that Bouguer calculated the series considering the meridians through the different points (on account of the proximity to the Equator) as perfectly parallel, while La

Condamine made allowance for the convergence of meridians. La Condamine also thought it proper to diminish the calculated length half as much as the measured length of the second base was less than the calculated length. Finally the distance of parallels of the Observatories erected near the extremities of the arc was found according to Bouguer, 176,940 toises, according to La Condamine 176,950.

Construction of the zenith-sector used in Peru.

The difference of latitudes was determined by observations of α Aquarii and θ Aquilæ, but more particularly of ε Orionis. The sector which they carried out with them was of 12 feet radius, and had an arc of 30°, but they soon found the convenience and accuracy of reducing the extent of arc. The new arc they redivided in a very ingenious manner; and afterwards constructed another sector on the same principle. It was as follows. The zenith-distance of the star used principally at the Southern observatory was about 1° 41′. If the reader will consider the method of observing with the zenith-sector by reversion, as described above, he will find that it is only necessary to have two points on the limb settled with great accuracy (one on each side of the centre) whose distance is nearly 2 × 1° 41′, or 3° 22′. Now the chord of the arc of 3° 22′ 15″ is $\frac{1}{18}$th of the radius. To divide an assumed radius into 18 equal parts is not easy: but it is very easy, assuming the length of the chord, to multiply it 18 times, and thus form the radius. This they accordingly did; then describing an arc of a circle, and taking on it two points at the assumed distance, the graduation was completed. The observation was made by moving the instrument till the plumb-line fell on the point, and a wire in the field of view of the telescope was then moved by a micrometer-screw, till the star was bisected. For the Northern observatory, the zenith-distance of the stars being less, they used in the same manner the arc, whose chord = $\frac{1}{20}$th of the radius.

In the first sector the telescope was connected with the principal bar of the sector by supports of several inches in length. The connection appeared to be not sufficiently firm, and they reduced the length of the supports. After numerous observations it still appeared that the telescope bent or deviated in some manner, and that no confidence could be placed in the instrument. At last Bouguer rivetted all the screws, and wrapped the bar and telescope round and round with iron wire. From this time the results were perfectly consistent.

Another difficulty now presented itself. If the same instrument were used to determine the latitudes of both extremities, as the apparent places of the stars would change between the observations, a perfect acquaintance with their apparent motions was necessary. But the laws and magnitudes of the newly discovered corrections for nutation and aberration were not then sufficiently known to enable them to calculate accurately the apparent places. But having constructed another sector, they determined on observing the same star simultaneously at both extremities. Bouguer accordingly went to Cotchesqui the Northern extremity, and La Condamine to Tarqui the Southern, and at length a satisfactory conclusion was obtained. More than three years, however, had been spent in determining the difference of latitudes. They fixed on 3° 7′ 1″.

One reduction remained. The length of the projection of the arc on the level of the lowest station was found, but it was necessary to find the length of the projection on the level of the sea. To ascertain the height of the lowest station above the sea was difficult, as the mountains between it and the sea were not visible at the coast on account of the constant fogs hanging on the forests below the mountains. At last they found that two of the peaks were visible from an island in the Emerald River; and they finally succeeded in ascertaining the height of the lowest station to be 1226 toises. The length of a degree at the level of the lowest station according to Lacondamine was 56,770 toises, and therefore at the level of the sea 56,749. Bouguer, however, made it 56,746; but he observed that this ought to be increased by seven toises on account of the expansion of the iron toise when compared with the wooden measuring-rods. Delambre recalculated this degree; he found the difference of latitudes to be 3° 7′ 3″; and the length of the degree 56,737 toises.

Value of this measure.

We have the advantage of possessing different accounts of this survey written by persons, each of whom had made nearly enough of independent observations to obtain a result. They had calculated the observations, each in his own way; and their personal friendship was not so ardent as to prevent either of them from pointing out any thing unfair in the proceedings of the other. When to this we add that it was one part of their system to make no important observation, if possible, without witnesses, it will appear that this arc is in all respects worthy of credit.

Methods pursued in the first Swedish measure.

In the Swedish measure conducted by Maupertuis, Clairaut, &c. the signals were commonly cones of barked trees, and the angles were observed with a two feet quadrant. The observed angles were reduced to horizontal angles. The azimuth was determined at Kittis (the Northern station) by observing the Sun's transit over the vertical of the next signal, the clock being regulated by equal altitudes. At Tornea the azimuth was found by observing the Sun near the horizon. The arc was calculated by parallels and perpendiculars, and allowance was made for the difference between a small circle and a great one. The base was then measured on the frozen river; eight rods were made each of four toises in length, and were compared with an iron toise (since called the *toise of the North*, and which had been compared with that used in Peru) at the temperature of 15° of Reaumur or $65\frac{3}{4}$° of Fahrenheit. The rods were laid on the snow; and two troops made independent measures which differed but four inches. The length was 7406 toises 5 feet; whence the distance between the parallels of the observatories was found to be 55,023.4 toises. The sector for determining the difference of latitudes was made by Graham. A detailed description of it may be found in the *Dégrè du Méridien entre Paris et Amiens;* it resembled, in most parts, the sector used by Bradley, now preserved in the Observatory of Greenwich. The telescope tube (which was large and strong, and nine feet in length) was itself the radius of the sector; it carried a limb of small extent, the graduation of which had been carefully verified. The whole was moved by a micrometer-screw acting in opposition to a weight, and care was taken that the screw should always act on the same point. The sector was not reversed, (according to the method of using this instrument described in our general account of it,) and thus the absolute zenith-distances of the stars observed were not determined. But as the same part of the limb was used in the observations of the same star at the two stations, the difference of zenith-distances, and consequently the difference of latitudes, was found, subject only to the error which might arise from disturbance in the relative positions of the telescope and the limb. The firmness of the instrument, (which consisted of but one piece,) the care used in transporting it, and the agreement of the results obtained after two transportations, seem fully to justify the Academicians in this use of the sector. Before the measure of the base δ Draconis was observed at Kittis and Tornea, five times at each; the difference of latitude (neglecting refraction) appeared to be 57′ 26″.93. After the measure of the base α Draconis was observed three times at each place; the difference of latitude was 57′ 30″.42,* the mean is 57′ 28″.7. In this estimation, refraction was not taken into account; it ought therefore to be increased by about 0″.7, which makes the difference of latitude 57′ 29″.4. Consequently the length of a degree is 57,425.5. We have stated in the first section that the later terrestrial measures in the same place, as far as they go, give results that agree perfectly with these. In order to make this measure and that of Svanberg agree in all points, it is necessary to suppose an error of 12″ or more in the French observations of latitude at Kittis.

Reasons for retaining this measure.

From the excellence of the instrument, the reputation of its maker, the care and fidelity of the observers, as shown in the points that have been examined, and the circumstance of their having repeated the observations under the fear that some error had crept into the first set, we have no hesitation in expressing our opinion that this is *impossible*. And we are glad to find that M. Rosenberger, after a careful examination of all the observations, (see the *Astronomische Nachrichten*, No. 121, 122.) has come to the same conclusion. From the difference of the altitudes of α and δ Draconis, compared with their known difference of declination, he has shown that the line of collimation was in the same state before the journey from and after the return to Tornea, as well as before the journey from and after the return to Kittis. And from observations made in France with the same instrument, (see the *Dégré du Méridien entre Paris et Amiens*,) it appears that after repeated voyages the line of collimation was not sensibly changed. The length of the arc which M. Rosenberger is inclined to adopt, is 55,020.16 toises, and the difference of latitude 57′ 30″.44; whence 1° = 57,405.02. The mean latitude is 66° 19′ 37″.

Methods followed in the verification of the arc of J. Cassini.

In the measure which forms the principal subject of the work entitled *La Méridienne Vérifiée*, a base of 6224 toises was measured near Dunkirk, one of 5094 toises near Amiens, one of 5749 toises near Paris, one of 7492 near Bourges, one of 4422 near Rodéz, and one of 7929 toises near Perpignan. The Dunkirk base crossed the entrance of the harbour. This part was not measured, but its length was ascertained by drawing a line perpendicular to the base, and finding by trial the point at which the rays coming from the signal made with this perpendicular an angle of 45°. The base measured near Bourges was one of the sides of a principal triangle. The base near Paris (on the road to Fontainbleau) was measured with four iron rods of 15 feet each; but all the others were measured with fir rods, well painted, and armed at the ends with iron caps. These wooden rods were 18 or 24 feet long, 3 or 4 inches broad, and 2 inches thick; they were compared three times each day with four iron rods of 3 feet each, which had been compared at the temperature of 14° of Reaumur, (63° of Fahrenheit,) with a line of 10 toises traced in the *salle de la Méridienne* of the Observatory at Paris. The mean of the difference was applied as a correction to the length of the wooden rods; it would appear also, (though we have not found any distinct statement,) that a correction was applied for the temperature of the iron rods at the time of comparison. In all cases the rods were applied end to end. The bases were measured at least twice: that near Paris five times. In the bases of Bourges and Rodéz, the angles made by the rods with the horizon were observed, and allowance made for the inclination.

The signals were generally church-towers, windmills, &c.; in a few instances it was found necessary to erect posts or other signals where no conspicuous object could be found.

The angles were measured with a quadrant of two feet radius, and were reduced to the centre of the station. The observed angles were altered to make the calculated lengths of the bases of verification and the calculated azimuth agree with those observed; but in no case did the alteration exceed 5″.

The azimuth of one side of a triangle was determined at each of the principal stations, (Dunkirk, Paris, Bourges, Rodéz, and Perpignan,) by observations of the Sun near the horizon.

South of Bourges, the observed angles were reduced to horizontal angles. The calculation of the terrestrial arc of meridian was made by the method of parallels and perpendiculars.

The sector for celestial observations was of 6 feet radius, and had an arc of 50°, divided by means of its index. The general accuracy of the arc was verified by taking angles all round the horizon, and observing whether their sum amounted to 360°; and the equality of the divisions, by determining the zero point from observations of different stars. The telescope had an internal micrometer. The only stars on which their determinations rest, are α Lyræ, α Cygni, α Persei, Capella, γ Draconis, and η Ursæ Majoris. Each star was observed eight or ten times at each station; and the sector was several times reversed in the course of each series. The final result was, that the length of the arc between Dunkirk and Paris was 125,431 toises, and its amplitude (or the difference of latitudes of the extremities) 2° 11′ 50″.26; between Paris and Bourges, 99,990 and 1° 45′ 7″.33; between Bourges and Rodéz, 155,767 and 2° 43′ 51″.5; between Rodéz and Perpignan, 94,308 and 1° 39′ 11″.2. The latitude of Paris was supposed to be 48° 50′ 10″, or 48° 50′ 12″. Of the excellence of this measure we conceive there can be no doubt.

Method used by Boscov

In the survey conducted by Boscovich, the bases were measured with wooden rods of 27 palms (about 18 French feet) each. These were compared continually (by means of beam-compasses, as described in our general account) with an iron rod of 9 palms, that had been measured by a French iron toise,* furnished by Mairan. Corrections for temperature were applied: the

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* About 1″ of the difference of these results depended on the inequality of the degrees on the limb, as ascertained in the verification.

* It is stated in a note to the French translation of Boscovich's Work, that this toise was shorter than the *toise of Peru* by $\frac{6}{15}$ of a line, and shorter than the *toise of the North* by $\frac{1}{15}$ of a line. The latter is the same as the toise used in the French arc last described. We know not on what authority the difference between the *toise of Peru* and the *toise of the North* is given: in every other statement that we have seen they are asserted to be equal. See the *Base du Système Métrique*, tom. iii. p. 413; where the comparison of Mairan's toise with the others will be found.

standard temperature was the same, we presume, as that adopted in the Peruvian measure, or 13° of Reaumur's scale. The base near Rimini consisted of two parts, making an angle of 176° 52′ 15″; a part of it crossing a river was measured by a triangle. The rods were supported on trestles; they were not placed in contact, but the distance between their extremities was measured. In uneven ground they were placed in a horizontal position; and the end of one rod was made to touch a plumb-line suspended from the end of the other. Allowance was made for the curvature of the rods when it appeared sensible. The signals were a sort of pyramidal huts, made of large branches of trees. The angles were measured with a quadrant of three feet radius, made by a priest. The triangles were calculated in the same manner as those of Peru. The azimuths were determined by three observations of the setting Sun at Rome, and three at Rimini. The length of the meridian arc was found by parallels and perpendiculars, calculating from the base of Rimini, to be 123,221.3 toises. The sector for celestial observations (made by the same priest) was of nine feet radius; it was similar to that described in our general account, with this difference, that the object-glass as well as the eye-piece of the telescope were attached to the bar, and independent of the intermediate tube; and that the graduations were upon a straight piece, sliding in a groove with a micrometer-screw, forming, in fact, a line of tangents divided into equal parts. The bar, &c. were of iron, and the slider of brass, and an apparatus was made for observing whether the difference of expansion would produce any sensible effect: Boscovich states that he never found it sensible. The stars observed were α Cygni and μ Ursæ Majoris: the number of observations 48. Between the first observations at Rome and the observations at Rimini, the line of collimation had altered its position by more than 2′; and on repeating the observations at Rome, its position was again changed. But as the sector was reversed several times during each series of observations, and the results of the different observations of each series agreed very well, there seems no reason for doubting the accuracy of the ultimate result. The mean amplitude is 2° 9′ 47″, whence 1° = 56,966.8 toises. But as the base near Rome was greater by the measure than by calculation, and some of the sides are lengthened by a different calculation, (Boscovich does not specify what,) and as some of the celestial observations appeared preferable to the rest, Boscovich adopted as the length of 1°, 56,979 toises. As Mairan's toise was shorter by $\frac{1}{29}$ of a line than the toise of Peru, these numbers ought to be diminished by $\frac{1}{25000}$ of the whole. The mean latitude is 42° 59′.

We have given every thing which seems necessary to enable the reader to judge of the value of this measure. Objections have been made to some parts of it by the Baron de Zach. (*Correspondance Astronomique*, vol. vi.) The azimuth observed at Rimini was reobserved by Zach, and the results differ more than 1′. From whatever source it rises, this is of no consequence, as the chain of triangles follows very nearly the direction of the meridian. The same Astronomer has calculated from the observations of Boscovich the latitude of Rimini, and finds that it differs nearly 4″ from that which he has determined by 110 observations of Polaris and α Aquilæ with a repeating-circle. But there is a fallacy in his mode of observation. The advantage of observing, with a repeating-circle, stars on both sides of the zenith, consists in this: that if the declinations of these stars have been determined by an instrument which has no constant error, the constant error of the repeating-circle will be eliminated from the result. But the declination of α Aquilæ used by Zach, was determined by the same repeating-circle, and differs from that commonly used; consequently, his results are affected with the constant error which affects the observations of Polaris. And as the sector of Boscovich was reversed three times during the observations of α Cygni at Rimini, and five times during those of μ Ursæ Majoris, we cannot allow the result to be set aside for any observations made with a repeating-circle.* From the appearance of the observations, and the character of the observer, we consider that great reliance may be placed on the results of this measure.

Methods followed in Lacaille's Measure at the Cape of Good Hope.

The standard used by Lacaille was an iron toise, constructed by the same artist who made the toise of Peru and the toise of the North. From this was made a wooden toise, terminated with brass plates, and exactly of the same length. By means of these, the measuring rods (four fir-rods, each 18 feet long, 3 inches broad, 2 inches thick, and well painted) were verified four times each day. Nothing is mentioned of a correction for temperature; Lacaille merely observes, that the sky was clouded and the South-West wind strong, and that nothing was to be feared on the score of temperature. It would seem that the rods were laid on the ground: Lacaille himself made the contact. Only four triangles were used. The signals were fires, rocks, &c. The angles were measured with a three-feet quadrant; and reduced to the centre of the station and to the horizontal angle. The azimuth was determined by 17 observations of the rising Sun at the Cape Observatory, which was the Southern extremity of the arc. The meridian arc was computed by parallels and perpendiculars. The amplitude was determined from observations made with the same sector which was used in the verification of the French meridian. Sixteen stars were observed at the Northern station (Klipfonteyn) for six days, the sector being three days in one position, and three days in the reversed position. The number of observations at the Cape was more considerable; they are to be found in Lacaille's *Fundamenta Astronomiæ*. The statements of Lacaille respecting the error of collimation (*Astron. Fund.* p. 158.) appear quite satisfactory. The deduced amplitude with Lacaille's last corrections (*Fundamenta*, p. 184.) was 1° 13′ 17″.5; the meridian arc 69,669.1 toises; whence 1° = 57,034.4 toises. The mean latitude 33° 18½′.

It is proper to remark, that Lacaille was so much surprised at this result, that he repeated the measure of the base and all the calculations. The observations of terrestrial angles and celestial zenith-distances did not seem subject to any doubt. Whatever be the consequence, we conceive that this measure must be received as equally certain (excepting, perhaps, some doubt about the trifling correction for the temperature in the measure of the base) with any of the former, and almost any of the subsequent measures.

The localities have since been examined by Captain Everest:† (*Astronomical Transactions*, vol. i.) it ap-

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* We have just received (through the kindness of the author) Mr. Rumker's observations made at Paramatta. The difference of the latitudes as found by the mean of many repetitions North of the zenith, and the mean of many South of the zenith, is 16″. The instrument is made by Reichenbach.

† We believe that if this distinguished officer had not been pre-

pears that there are large mountain masses to the North-West of the Northern extremity, and to the South-West of the Southern extremity, the effect of which would be to diminish the apparent difference of latitudes.

Methods used by Liesganig.

In Liesganig's arc, the standard was an iron toise, compared, at the temperature 13° of Reaumur, ($61\frac{1}{4}$° Fahrenheit,) with the *toise of Peru*. The measuring rods were each six Vienna fathoms long, spliced like the mast of a ship; they were laid on the ground, and placed in contact. The angles were observed with a quadrant of $2\frac{1}{2}$ feet, that had been carefully verified; they were reduced to horizontal angles. The azimuth was determined by observations of the Sun near the horizon. The meridian arc was calculated by parallels and perpendiculars. The sector of 10 feet radius was similar in all respects to that of Boscovich; its divisions were verified. The stars observed were α and β Aurigæ, α and δ Cygni, γ Draconis, and ι Herculis, (set down as μ Draconis;) each star was observed three or four times in each position of the sector, which was only once reversed. The concluded amplitude was 2° 56′ 45.″5; and the concluded arc of meridian 172,796 Vienna fathoms = 168,149 toises.

We have already stated the reasons for rejecting this measure. If we adopt for the Southern part of the arc the numbers given by the later survey, we ought to increase the meridian arc by 264 toises. But it appears from Zach's statements, (who, however, is no friend to the Jesuits,) that the astronomical observations were falsified. It will be better upon the whole to reject any conclusion derived from this arc of meridian.

Methods pursued in Beccaria's measure.

In the survey made by Beccaria, the base was measured with wooden rods laid on trestles. Two small parts were added by triangulation. The toise (compared at 13° of Reaumur with the toise of Peru) was furnished by Lacondamine: and the correction used for the temperature was Lacondamine's. The signals in general were posts. The angles (observed with a quadrant like that of Boscovich) were reduced to horizontal angles, and these to the angles formed by the chords. The azimuth was observed, and the calculations made, as in the last-described surveys. The sector* was nearly similar in construction to that of Boscovich. The stars observed were α and δ Cygni, and β Aurigæ: the sector was reversed twice or three times at each place. The details of the micrometer readings, &c. are not given. The concluded distance and amplitude were 64,889.6, and 1° 7′ 44″.71, the extreme difference of the results from the three stars amounting only to 2″. It is unnecessary to enter into greater details, as the same line has since been surveyed by MM. Plana and Carlini, whose conclusions (which we shall shortly give) are undoubtedly more accurate than those of Beccaria.

Methods used in North-America arc.

In the measure of the line between Maryland and Pennsylvania, by Mason and Dixon, the whole was measured with two "rectangular levels, or measuring frames." As we do not perfectly understand the description of them given in the *Phil. Trans.* 1768, we shall copy it *verbatim.* "The levels used in this work were each 20 feet in length, and 4 feet in height. They were made of pine, an inch thick, and in form of a rectangle; the breadth of the bottom board was $7\frac{1}{2}$ inches, that of the top 3 inches, of the ends $4\frac{1}{2}$ inches, and the bottom and top were strengthened with boards firmly fixed to them at right angles. The joints were secured with plates of iron, and the ends were plated with brass. The plumb-lines used in setting them level were 3 feet 2 inches in length, and hung in the middle of the levels, being secured in a tube from the wind, in the manner of carpenters' levels; wherefore we called these by the same name." The levels were frequently compared with a brass standard of 5 feet, and the temperature was noted. The allowance for expansion was taken from Smeaton's experiments, and the length was reduced to what it would have been if the brass rod had been used at the temperature 62° of Fahrenheit. By fixing in the ground a stake with a movable piece of iron, which was brought to a certain mark on each level, it was easy to observe whether one level moved when the other was placed in front of it. The line was carried over a few rivers by a triangle, as in the former surveys. For the azimuth, a clock was regulated by equal altitudes, and the clock time of stars' culminations being found, a transit-instrument was directed to them at that instant, and by means of it a meridian mark was fixed; thus the azimuth of a given line could be found, or the direction of a meridian could be fixed. The lines measured were the following. N P, fig. 35 = 78,290.72 feet, in the direction of the meridian: P a = 2,991 miles; this line is in such a direction that if continued to the length of 10′ of a great circle, it would meet the parallel of latitude passing through P: a C = 45.5 feet, in the meridian. C D = 26,608.06 feet, in the direction of the meridian. (These two parts were measured separately from a mistake in fixing the point C, which ought to have been in the parallel of P.) D B = 1491 feet; and the angle C D B = 93° 28′. B A = 434,011.64 feet, making an angle of 3° 43′ 30″ with the meridian. Hence, the distance of the parallels of N and P is 78,290.7 feet; that of P and a, − 14.1; that of a and C, 45.5; that of C and D, 26,608.1; that of D and B, 89.8; that of B and A (computed as described in our

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vented, by his absence from Europe, from consulting Lacaille's account of the survey, he would have found that some of his objections were without foundation. Lacaille states that the ground was cleared and levelled for the base measure; he states that the instruments were not placed at the centre of the stations, (which was rarely done before the English survey,) and gives the numbers necessary for the reductions. The magnitude of fires visible at the distance of 45 miles need not, perhaps, be so great as to throw any great uncertainty on the terrestrial measure. The instability of the observatory, though always injurious, is of comparatively little consequence, we conceive, in observations with the zenith-sector, and, with reasonable care, its effects can be easily detected.

* Through the politeness of the Members of the Turin Academy we have been allowed to examine this sector, which is now preserved at their apartments. We are at a loss to conceive how such errors can have been committed as those attributed to Beccaria's observations. The tube containing the object-glass appears to be firmly attached to the bar; and the object-glass, though not quite tight in its cell, is tight enough to prevent accidental derangement. This tube is unconnected with the rest of the tube. The eye-piece also appears to be firmly connected with the bar. The object-glass-tube projects about two inches beyond the last of its two supports, and the eye-piece about four inches beyond the last of its supports. Can the weight of the telescope tube (weakly attached to the axis) have twisted the eye-piece? Or are the divisions of the tangent-scale, or the length of the radius, wrongly estimated? No other explanation suggests itself to us. It must be remarked that the wires in the eye-piece, and the plumb-line, are wanting: the pin for the plumb-line suspension is as good as those commonly used. We have no hesitation in saying that we should place more confidence in the observations made by any careful person with this instrument, than in those made with Mechain's circle. The character of the observer, as it appears to us, can alone explain the errors of the observations.

general account) 433,078.8; whence the distance of parallels of N and A is 538,098.8 feet. As the five-feet brass rod, on comparison with the Royal Society's standard, was found to be too short by $\frac{13}{360000}$ of the whole, these numbers ought to be diminished by 19.4; and the distance of the parallels is 538,079.4 feet. By a comparison of the standard just mentioned with the toise of Peru, instituted on this occasion, it was found that the toise = 76,734 inches; whence the distance of the parallels = 84,147.2 toises.

The observations of stars were made with a six feet sector, constructed by Bird, in which the plumb-line was made to bisect a dot at the centre of the instrument. The stars observed were α Lyræ, γ Andromedæ, β Persei, δ Persei, β Aurigæ, Castor; Capella also was observed, but the result disagreeing a few seconds from that given by the others, was rejected. Each star was observed at N and P, three or four times in each position of the sector. The sector was reversed only once at each station. Finally, the difference of latitude = 1° 28′ 44″.99, and the mean latitude 39° 12′; whence 1° = 363,772 feet = 60,628.7 fathoms = 56,888.3 toises. The Royal Society's standard yard has been found by Capt. Kater (*Phil. Trans.* 1821) to be longer than Shuckburgh's by .001365 of an inch; whence the distance of parallels is 538,099.8 feet, and 1° = 363,785 feet = 60,630.9 fathoms, by Shuckburgh's standard.

The only chance of error in this operation consists (we conceive) in the possibility of losing in the measure some whole number of level-lengths. This was provided against with tolerable certainty by previously measuring the whole line with a chain, and fixing posts at certain distances. Of the goodness of the astronomical observations we think there can be no doubt. The results of this measure must, we think, be received as equal in authority to those of any other measure.

The survey of 1787, connecting the meridians of Greenwich and Paris, has sometimes been used in the estimation of the degree deduced from the French measures. The meridian arc, of which the Southern extremity is in France, has sometimes been a little extended by taking Greenwich for its Northern termination. We mention this only to record our protest against such an extension. The chain of triangles connecting the meridians runs East-South-East, and West-North-West, and is of considerable length, and consequently the smallest error in the azimuth (which it is impossible to avoid) will produce a considerable error on the length of the meridian arc.

The bases on which the operations of Delambre and Mechain were founded, (at Melun and Perpignan,) were measured with rods of platinum, 2 toises long, 6 lines broad, and 1 line thick. To each was attached, at one end, a rod of brass; the proportion of the expansions of brass and platinum being known, the expansion of the platinum rod was inferred from the observed difference of expansion of the two rods. This apparatus was enclosed in a wooden box. Four of these compound rods were used: they were placed on trestles, not in contact, the distance being measured by a small slider. The lengths of the bases were expressed in numbers of the length of the toise of Peru, taken at the temperature of 13° of Reaumur, or 61¼° of Fahrenheit.* Allowance was made for the inclination of the bars. The bases consisted each of two parts, making a small angle. The length of the base of Melun was 6075.9 toises· that of Perpignan 6006.25. The length of the latter calculated from the former, through the chain of triangles, differed only 11 inches from the measured length. The angles were observed with repeating-circles. The triangles were calculated as spherical triangles, by Delambre's method. (TRIGONOMETRY, Art. 182.) The azimuths were determined by observations of the Sun near the horizon, and by measures of the angular distance of a signal from the Pole-star. (TRIGONOMETRY, Art. 185.*) The arc of meridian was then calculated by the method which (in our general account of methods) we have described as Delambre's. In the prolongation of this arc to Formentera, the same methods were used, except that the azimuth was ascertained by transits as described in TRIGONOMETRY, Art. 185. The latitudes were found almost entirely by observations of the Pole-star, and β Ursæ Minoris, made with Lenoir's repeating-circle. To give an idea of the extent to which this instrument was used in these determinations, it will be sufficient to state that the latitude of Formentera was fixed by 2500 observations of Polaris, and 1400 of β Ursæ Minoris.

We have already mentioned the discordances in the observations of Mechain at Barcelona and Montjouy, and the doubt thrown by them on the results of observations with the repeating-circle. They have been considered by M. Nicollet in the Memoir before referred to, (*Conn. des Temps.* 1831, *Additions*:) and his conclusions (omitting every thing relating to the inability of the telescope to separate ζ Ursæ Majoris) appear to us perfectly correct. Mechain's observations at these places were not confined to the Pole-star and β Ursæ Minoris, but included several stars passing to the North, and several passing to the South of the zenith. Now M. Nicollet shows that if we use Piazzi's declinations, and find the latitude of each place, first by a mean of the observations of stars passing North of the zenith, and next by a mean of those of stars passing South of the zenith, and take the mean of these results, the difference of latitudes is almost precisely what we should have expected from the known distance of parallels; and thus the difficulty disappears. It has been answered, (*Philosophical Magazine*, March 1829,) that if we compare the observations on the same stars made at the two stations, as with zenith-sector observations, the original difficulty remains. But we think that the author of this answer has not sufficiently considered the nature of the defect attributed to repeating-circles. Of the stars observed at both stations, only one passes South of the zenith. Now if the *constant error* of the circle had undergone any alteration (as is probable after the interval of a year) *all* the stars North of the zenith would give the same error, and with the same sign in the difference of the latitudes. But the stars South of the zenith would give the same error with a contrary sign, and in fact the only South star observed

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* As there has been a little confusion respecting these reductions for temperature, the reader is referred to the *Phil. Trans.* 1826, p. 568, for an abstract of all the passages in the *Base du Système Métrique* relating to this point, as well as to the comparison of the new standard with the ancient and foreign standards.

* In the Essay on TRIGONOMETRY to which we have referred, it is said that the azimuth is determined by a right-angled spherical triangle. This is only true when the signal is exactly in the horizon; when it is elevated or depressed, it is necessary to calculate the zenith angle of the triangle, whose angles are at the zenith, the Pole, and the signal.

at both places, gives a discordance of an opposite kind. We think, therefore, that M. Nicollet is quite right in fixing the latitude of Montjouy at 41° 21′ 44″.535.

The latitude of Mountjouy is, however, of no essential importance. It is much to be wished that the latitudes of Dunkirk and Formentera were determined with greater certainty. The latter rests on an enormous number of observations, but entirely on stars North of the zenith, and with a circle whose level was attached to the axis; it is probably subject to a much greater error than if it had been fixed by ten observations with Graham's or Ramsden's sector. In the determination of the latitude of Dunkirk, many observations were rejected; and in that of Paris, Mechain rejected observations by thousands, apparently preserving only those whose results presented the greatest agreement. The latitudes of the other intermediate points are still more doubtful. In our present uncertainty we shall adopt from the *Base du Système Métrique* the following numbers: latitude of Dunkirk 51° 2′ 8″.7; latitude of Formentera 38° 39′ 56″.1; distance of parallels 705,189.4 toises; mean length of degree 57,007 toises.

Svanberg's methods.

The base measured by Svanberg was nearly in the same line as that measured by Maupertuis and Clairaut. The measuring rods were iron bars of six mètres each. The observed length was corrected for the flexure of the bars, their horizontal inclination with the direction of the base, &c., but the correction for temperature remains uncertain from a cause which deserves a distinct explanation.

On the manner of using standard measures.

By a toise, or a yard, or a mètre, we mean a certain extent of space in one direction, without any reference to wooden rods or metallic bars. But as it is impossible to measure a line without some material standard, we are compelled to adopt as the practical definition of a toise or a yard, &c. the length of a certain bar of metal, called a standard. If this length be invariable, the measure is fixed without any further condition. But if from change of temperature, or any other change of circumstances, the length of the bar (as compared with the length of others not subjected to the same trial) be found to change, then we must specify the degree of temperature, and the other circumstances under which this certain bar must be placed in order to present the exact length required. If then the length of a base, or the length of a pendulum, has been measured with the standard, at a higher temperature than that specified, and if we know that at this higher temperature the bar was longer than at the specified temperature, it is plain that the length of the bar has not been contained so many times in the line measured as it would have been if used at the specified temperature, and, consequently, the resulting number (which expresses how often the length of the bar is contained in the line) must be increased. Similarly if measured at a lower temperature the number must be diminished.

Reduction for temperature.

It was not till geodetic measures had acquired considerable accuracy, that this refinement was thought of. And when necessity compelled Philosophers to fix on some temperature for the measure of the standard bar, convenience directed them to choose one which could be commanded at all times with little trouble, and which was as likely to occur in ordinary measures as any other. Thus the French toise was the measure of the iron bar called the *toise of Peru* at the temperature of 13° Reaumur, or 61½° Fahrenheit, or 16¼° Centigrade; the English yard was the measure of a brass bar, (or rather some one of several brass bars,[*]) at the temperature of 62° Fahrenheit.

Temperature for the old standards.

But the new French measure was adopted at a time when all other considerations gave way to theory. The mètre is *defined* by 443.296 lines of the toise of Peru, at the temperature 13° of Reaumur. But it is *represented* by the length of a standard platinum bar, at the temperature of freezing water, or 0° of Reaumur's and the Centigrade scale. This change of temperature for the measure of the standard, has introduced no little confusion into the subject of measures generally.[†] In the instance now before us, additional confusion is introduced by the change of the metal used for the construction of the standard.

It is uncertain whether the iron bar used by Svanberg was compared with the platinum standard preserved at Paris, at the temperature of 0°, or 16¼° Centigrade. If the expansions of the two metals, with the same change of temperature, were the same, this would be of no consequence. But their expansions being different, if the two bars had the same length at the temperature 0°, they would not have the same length at the temperature 16¼°. If they were compared at the temperature 0°, it would be right to apply to the measured length of Svanberg's base, the correction corresponding to the expansion of iron between 0° and the observed temperature. If compared at the temperature 16¼°, the length must be corrected for the expansion of iron, between 16¼° and the observed temperature, and for the expansion of platinum between 0° and 16¼°. It is most probable that they were compared at the temperature 0°.

The signals for Svanberg's triangles were so constructed as to allow the light of the sky to be seen through them. The angles were observed with repeating-circles. The azimuths were found by observing the transits of the Pole-star and other stars over the same vertical; from equal altitudes of stars; and from observations of the Sun. The triangles and arc of meridian were calculated by Delambre's method. The latitudes were found by a great number of observations on the Pole-star, made with Lenoir's repeating-circle. The final results are, that the distance between the parallels of Mallorn and Pahtavara is 180,827.68 mètres = 92,777.98 toises, (or 180,794.06 mètres = 92,760.73 toises, if the standards were compared at the temperature 16¼° Centigrade;) the latitude of Mallorn = $72^{g}.8056872$ = 65° 31′ 30″.26; the latitude of Pahtavara = $74^{g}.6079728$ = 67° 8′ 49″.83; whence the difference of latitudes = 1° 37′ 19″.57. This ought to be diminished by 0″.28, because in the calculation of nutation, the true place of the Moon's node has been used instead of the mean place. Hence 1° = 57,198.9 toises.

There is no doubt of the general excellence of this measure. The astronomical determinations, we conceive, are not equal to those in the measure of the French

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[*] For a comparison of Shuckburgh's, Bird's, Roy's, Ramsden's, and the Royal Society's standard, the reader is referred to a paper by Capt. Kater, in the *Philosophical Transactions*, 1821.

[†] The reader, who may think this explanation unnecessary, is referred for a proof of the confusion on this subject to the *Phil. Trans.* 1818, where Col. Lambton has applied an unnecessary correction to the length of the French arc; to the *Phil. Trans.* 1822, where Mr. Goldingham has applied a correction with the wrong sign to the length of the seconds' pendulum at London; and to Zach's *Correspondance*, vol. viii. p. 150, where Zach has fallen into an error in the comparison of Beccaria's toise with the French mètre.

Academicians in the same Country, but they are as good as could be made with the instrument employed. The anxiety of Svanberg and his companions to omit no reduction, whose value could be sensible, has led them into many refinements that are useless, and some that are erroneous,* but none to such an amount as to hurt the credit of the result.

The rods with which the first base was measured in England were thin glass tubes, 20 feet long, and about an inch in diameter, enclosed in wooden boxes, (except at the ends,) and supported on trestles. Each rod had at one end a small slider driven outwards by a weak spring; and the succeeding rod was pressed against it till the slider was pushed up to a certain point. But the apparatus ultimately adopted was a steel chain of 100 feet in length, consisting of forty links. One chain only was used in the actual measure, but another was carried for the purpose of occasional comparison. The mode of measuring finally employed was this. The chain was supported in several troughs resting on trestles, and extended by a weight of 28 pounds. In any position of the chain, two posts were necessary at each end. One post at the preceding end carried a pully, over which passed the rope sustaining the weight which stretched the chain. To one post at the following end was fixed an apparatus of screws, by which the chain was supported in opposition to the action of the weight, and by which it could be moved slowly. The other post at the following end of the chain carried a scale, to one division of which a mark on the end of the chain was brought by the screw motion; and the other post at the preceding end carried a scale, of which one division was brought by a screw motion to a mark at that end of the chain. When the chain was moved to the next position, the mark on the following end of the chain was brought to that division of the scale with which the mark on the preceding end had coincided. It will easily be seen that the correctness of the operation depends on the immobility of the scale-posts, (which are subject to no strain,) and that in fact three posts at each end were necessary. The expansion of the glass tubes and of the chain were determined by experiments expressly made for the measure. Corrections were applied for the temperature, the inclination, and the height above the sea. The length of the base on Hounslow Heath was 27,404 feet; of that on Salisbury Plain 36,575; and of that on Misterton Carr, (near the Northern extremity of the arc of meridian,) 26,842 feet. Several other bases were measured in different parts of the Kingdom.

The signals were usually flag-staffs, or white lights. The angles were observed with a large theodolite, made by Ramsden, three feet in diameter; an instrument undoubtedly superior to any other that had been used in similar observations. As with this instrument the horizontal angle was immediately observed, no reduction for the height of the signals was necessary. The horizontal angles were reduced to chord angles. The first azimuth was obtained from the meridian mark of the transit-instrument at Greenwich Observatory; afterwards the azimuths were found by observing with the theodolite the Pole-star at its greatest azimuth. The meridian arc was computed by parallels and perpendiculars. The distance of the parallels of Dunnose (in the Isle of Wight) and Arbury Hill (near Daventry) was found to be 586,319.5 feet; that between the parallels of Dunnose and Clifton (near Doncaster) 1,036,337 feet; and that between the parallels of Dunnose and Burleigh Moor 1,442,852.5 feet. The chains were measured with Ramsden's brass yard, which it appears from Captain Kater's comparison (*Phil. Trans.* 1821) exceeded Shuckburgh's, now adopted as the standard, by .002505 parts of an inch, or $\frac{1}{14370}$ of the whole. Thus the meridional distances are found to be 586,360.3, 1,036,409.1, and 1,442,952.9 feet, when measured by Shuckburgh's standard.

Meridian Measures.

The difference of latitudes was determined by observations with a zenith-sector made by Ramsden, apparently the best which has ever been constructed. For a description of this superb instrument we must refer to the *Phil. Trans.* 1803, to the *Account of the Trigonometrical Survey*, vol. ii., or to Pearson's *Practical Astronomy*, vol. ii. It is sufficient here to state that the telescope was eight feet long, and carried the arc; that it was moved by an external micrometer; that the plumb-line bisected a dot at the centre; and that from a very severe examination it does not appear that the error of collimation was sensibly altered during the observations. For the difference of latitude of Dunnose and Burleigh Moor, eight stars were observed; those of the other stations were found by a greater number. In general each star was observed about eight times, the sector being reversed after every day's observation. The amplitudes were thus found to be, between Dunnose and Arbury Hill 1° 36′ 19″.98; between Dunnose and Clifton 2° 50′ 23″.38; between Dunnose and Burleigh Moor 3° 57′ 13″.1. The mean latitude of the last arc is 52° 35′ 45″; the length of 1° = 364,968.3 feet. The middle latitude between Dunnose and Arbury Hill is 51° 25′ 18″; the length of 1° = 365,208.4; the middle latitude between Arbury Hill and Clifton is 52° 50′ 30″; the length of 1°, 364,625.1; the middle latitude between Clifton and Burleigh Moor 54° 0′ 56″; the length of 1°, 365,002.5. By a comparison of the French mètre with Shuckburgh's standard, Captain Kater (*Phil. Trans.* 1818) has found the mètre = 39.37079 inches; and as the mètre = 443.296 lines of the toise of Peru, it follows that the toise = 6.394596 feet. Hence the distance between the parallels of Dunnose and Burleigh Moor = 225,651.9 toises. We believe the results of this measure to be far more exact than those of any of the measures hitherto described.

Methods used in the East-Indian survey.

The methods adopted by Colonel Lambton were in almost all respects the same as those used in the English survey. The base near Madras was measured with a steel chain which was occasionally compared with a standard chain that had been measured by Ramsden's brass standard when the temperature was 50° of Fahrenheit; the length of the base was therefore corrected for the expansion of the steel to this temperature, and

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* Among these we may reckon Svanberg's method of taking the mean of observations made with the repeating-circle. Instead of taking the difference between the first and last readings, and dividing by the number of multiplications, he takes every possible combination of one, two, three, &c. multiples, and gives to each a vote proportional to its number. But it seems plain that every observation of a double angle is perfectly independent, (as the telescopes are pointed anew for every observation,) and, therefore, we have no right to take two or three double angles together, as we should have if it were possible to observe at once four or six times the angle. Every observation being independent, and therefore all being à *priori* equal in accuracy, the probably best determination is the mean of all, that is the difference of the first and last readings divided by the number of multiplications. In the instance that he has mentioned, (p. 33.) the difference of determinations, by Svanberg's, and by the common method, is 1″.4.

for the contraction of the brass to the temperature 62°. The expansion of the chain was determined by independent experiments. Corrections were applied for the inclination, the height above the sea, &c. The same course was pursued in the measure of the base near Bangalore, of that in the Coimbetoor, of that near Palamcottah, of that near Gooty, and of that near Daumergidda: their lengths were respectively 40,006, 39,794, 32,301, 30,507, 32,609, and 30,806 feet. On comparing the chains previous to the measure of the base near Gooty, there appeared to be some reason for supposing that the standard chain had altered its length; and it was then compared by means of beam-compasses with a brass bar.

The signals were flag-staffs and white lights. The angles were observed with a large theodolite. The observed horizontal angles were reduced to chord-angles, and the triangles calculated as plane triangles. The azimuths were determined by observations of Polaris at his greatest azimuth, made with the theodolite. The meridian arc was calculated by parallels and perpendiculars; but the principal stations were so nearly in the same meridian that no allowance was made for the difference between the perpendicular and the small circle passing through a station. Two different meridians were, in fact, measured; in the first of these (near the Coromandel coast) the meridional distance between Trivandeporum and Paudree was found = 574,328 feet; and in the second, the distance from Punnæ (near Cape Comorin) to Putchapolliam = 1,029,101; that from Putchapolliam to Namthabad = 1,489,131; and that from Namthabad to Daumergidda = 1,073,428 feet. To reduce these to Shuckburgh's standard, it must be observed (*Phil. Trans.* 1823) that the triangles extending over the shorter meridian arc, and the Southern part and 105,996 feet of the middle part of the longer arc, were calculated from the measure by Ramsden's chain; and those on the rest of the middle part and the Northern part from the measure made with the brass bar. The former is too long by .00250 inch, and the latter too short by .00064 inch in every yard. The lengths thus corrected are 574,368, 1,029,173, 1,489,198, and 1,073,409 feet.

The latitudes were found by observations with a zenith-sector of five feet radius, constructed by Ramsden, and similar to that used in the English survey. It appears that its error of collimation changed by a very small quantity during the operations, but was steady enough at each station. For the determination of some of the amplitudes, seventeen stars were used, each of which had been observed eight or ten times, the sector being reversed after every day's observation. The absolute latitudes depended on a smaller number of principal stars. The final results were as follows: latitude of Trivandeporum 11° 44′ 52″.6; of Paudree 13° 19′ 49″.0; latitude of Punnæ 8° 9′ 38″.4; of Putchapolliam 10° 59′ 48″.9; of Namthabad 15° 6′ 0″.2; and of Daumergidda 18° 3′ 23″.5. The latitudes of some intermediate points were observed, and in one of them it appeared that the disturbance of local attraction was sensible. The length of 1° is, in the arc from Trivandeporum to Paudree 362,988 feet, in the Southern part of the long arc 362,864, in the middle part 362,941, and in the Northern part 363,071 feet.

Considering the extent of this arc,* as well as the exactness of every part of the operations, we do not hesitate to state our opinion that it is superior to every other that we have described.

Metho used in remeas ment o Beccar arc.

Some triangles observed by the Baron de Zach, for the estimation of the accuracy of Beccaria's measure, were founded on a base of little more than 600 yards in length. An erroneous reduction was applied for temperature, and the base was measured but once; MM. Plana and Carlini, therefore, measured a new base of nearly the same length, and in nearly the same situation. The measuring rods were of wood, 12 mètres in length, in the form of hollow parallelopipeds. To the preceding end of each was attached a metallic frame in the form of a hollow parallelogram and in the same plane as one side of the parallelopiped. A fine thread was stretched across this frame, so that when the rod was horizontal the thread was vertical. In measuring, every rod was placed horizontal upon trestles; the second rod was not made to touch the first, but was so placed that a fine dot near its following end was bisected by the thread carried by the frame on the preceding end of the first rod. By this simple contrivance the use of the plumb-line was entirely avoided, and there was no fear of disturbing one rod by the contact of another. The rods were compared after each of the two measures with a standard mètre, by means of a microscopic apparatus. Some triangles, observed with the repeating-circle, connected this with one of Beccaria's principal sides; and the rest of the triangles were observed by the surveyors of the French Government. A chain of triangles had also been observed, connecting Beccaria's with a base measured near the Ticino; and others connecting it with the triangles crossing the Alps, and ultimately with the bases measured in France. The results from the different bases agreed very nearly. The azimuth was determined at the Observatory of Turin, from the meridian mark of the transit-instrument. The parts of meridian were calculated by Delambre's formulæ. The length of Beccaria's arc, deduced from the base on the Ticino, was 126,385.25 mètres, or 64,845 toises.

The latitudes were determined by observations made with a repeating-circle. At each extremity, Polaris, and two stars South of the zenith, as well as the Sun, were observed; several series of observations were made on each; the mean of the latitudes given by Polaris was taken as one determination, subject to the constant error of the circle, and the mean of the latitudes given by the other stars and the Sun, as another determination, subject to the constant error with the contrary sign. The mean of these was free from the constant error. Thus the latitude of Beccaria's station at Mondovi was found to be 44° 23′ 44″.37; that of Andrate 45° 31′ 15″.44, the amplitude 1° 7′ 31″.07, less by 13″ than that given by Beccaria.

The whole of this measure, and in particular the determination of the latitudes, seem to have been made with so much care, that we must allow its excellence. It is, in fact, almost the only one in which proper caution has been used in the determination of the latitudes with the repeating-circle.

Meth used Hano meas

The apparatus used in the Hanoverian* base-measure is described in a pamphlet, entitled *Schreiben an den Herrn Olbers von H. C. Schumacher, enthaltend eine Nachricht über den Apparat, dessen er sich zur Messung*

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* This arc has been extended by Captain Everest to latitude 24° 7′. The details are not yet published.

* We had not received the account of this and the following measure when the first section of this Treatise was sent to press.

der Basis bei Braack im Jahre 1820 bedient hat. Three bars of hammered iron were used, each 12 French feet in length, and 1$\frac{1}{4}$ inch broad and deep; the ends were armed with steel plates, at one end flat, and at the other spherical. They were carried in wooden boxes completely closed, the ends only projecting; to prevent flexure they were supported by counterpoises applied at different parts. The boxes were placed on trestles of variable heights; the rods were placed horizontal, and at the same height, as long as the nature of the ground allowed. A small interval was left between the flat end of one rod and the spherical end of the next, and this was measured by dropping between them a glass wedge whose depth was forty-eight times the thickness of its back. When it became necessary to alter the height of the bars, a cylinder of bell-metal was employed, which by means of a level was placed very exactly vertical, and the same glass wedge was used to measure the distance between the top of the cylinder and the upper bar, as well as between the bottom of the cylinder and the lower bar. Of the length of the base, and the details of the survey, we find no mention; and we believe that no further account has been published.

The difference of latitudes of the observatories at Göttingen and Altona, was ascertained by observations made with Ramsden's zenith-sector, (the same which was used in the English survey.) Forty-two stars were observed at both places; each about six times in each position of the sector. In general, the sector was reversed after each night's observation. The details will be found in the *Bestimmung des Breitenunterscheides zwischen den Sternwärten von Göttingen und Altona, &c. von* C. F. Gauss. The results were, latitude of the observatory at Göttingen, 51° 31′ 47″.85; of the observatory at Altona, 53° 32′ 45″.27; amplitude of the arc, 2° 0′ 57″.42. The last is, undoubtedly, one of the most accurate determinations ever made.

It is stated by M. Gauss that the observatory of Altona is 115,163.7 toises North, and 7.2 toises West, of that at Göttingen. This estimation is founded on the base mentioned above; the measuring bars have not been definitely compared with the French toise, but M. Gauss states, that it is impossible that there can be any serious error in the estimation. The resulting length of one degree is 57,127.2 toises.

The arc measured by M. Struve, and extending from Jacobstadt, on the Düna, to the island Hochland, in the Gulf of Finland, depends on a base of 2315 toises. This line was but once measured with iron bars of two toises in length, each of which carried at one end a lever of great sensibility, (*Fühlhebel,**) by which the contact with the next was made. By means of a microscopic apparatus, they were compared with a standard made by Fortin. To detect any error in the base measure, it was divided into two parts, and these were connected by a triangulation. The signals were poles supported by wooden pyramids. The angles were measured with Reichenbach's universal instrument, (a sort of theodolite,) in which the horizontal circle was 14 inches in diameter. For the azimuths, the Pole star was observed with the same instrument, at Jacobstadt, Dorpat, and Hochland; at Dorpat, also, another determination was obtained from the meridian-mark of the transit-instrument. The triangles were calculated by Legendre's theorem, and the distance of parallels by a method explained by Bessel in the *Astronomische Nachrichten*, No. 3. It consists in supposing arcs of great circles, A D, A F, &c., drawn from the station at one extremity A of the chain, fig. 36, to each of the other stations, and calculating each of the triangles A B D, A D F, &c., either as spherical triangles, or with the assistance of Legendre's theorem as plane triangles. Thus knowing A B, B D, and the angle A B D, the side A D and the angles B A D, B D A are found. Subtracting B D A from the sum of B D C, C D E, E D F, the angle A D F is found; and A D, D F, are known: hence A F, F A D, A F D, are found. This process is continued to the last station, as F; then all the angles at A being known, and the azimuth of A B being known, that of A F is known; also the length of A F is known; and then the distance of the parallels can easily be found by either of the methods already explained. The amplitude was found from observations of γ, ζ, and η, Ursæ Majoris, with an eight-feet transit-instrument adjusted to move in the prime vertical. It was carefully levelled, and was reversed after each night's observation. The clock (upon the goodness of which the exactness of this operation entirely depends) was made by Repsold. The latitudes were also determined by observations of Polaris and β Ursæ Minoris, with 18-inch circles made by Reichenbach: allowance was made for the flexure of the telescopes. By a mean, the latitude of Jacobstadt was found to be 56° 30′ 4″.7; that of Dorpat, 58° 22′ 47″.4; that of Hochland, 60° 5′ 9″.9. The terrestrial distances of the parallels were, from Jacobstadt to Dorpat, 107,281.6 toises; from Dorpat to Hochland, 97,538.5 toises. The lengths of 1° given by these parts are 57,108.8, and 57,165.5 toises. M. Struve remarks that the general flatness of the country, and the apparent absence of disturbing causes, would not have led him to expect so great a difference. An abstract of these operations will be found in the *Astronomische Nachrichten*, No. 164.

Meridian Measures.

Bessel's method of calculating the distance of parallels.

The method of determining the latitude by transits (upon which it appears that M. Struve principally relied) has been so little used that we are unable to form a decided opinion on its merits. But the well-known character of the observer, and the caution evidently employed in every part of the operation, leaves no doubt of the general accuracy of these results.

Continuation of the Indian arc.

Since the last sheet was sent to press, the account of the continuation of the Indian arc by Captain Everest, mentioned in the note to p. 212, has been published. The new bases at Takal Khera (near Ellichpoor) and near Kulliampoor, (in the vicinity of Seronj,) were measured with the same chain and referred to the same brass bar which Colonel Lambton had used. Their lengths were 37,913 and 38,412 feet. Night-signals were generally preferred, as it was found that in the healthy season of the year the nights were very favourable, and the magnitude of terrestrial refraction at night such as to make stations visible which were not visible in the day. The large theodolite with which the greater part of the triangulation was performed had sustained much injury from an accidental blow while used by Colonel Lambton for the purposes of general geography, and the limb was completely distorted. Colonel Lambton, however, by the use of wedges,

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* We are not acquainted with the construction of this instrument.

screws, pullies, and wooden hammers, restored the circle so nearly to its original shape, that the difference between the readings on any point of the limb, and on the point 90° from it, did not exceed 26″. By altering the zero point nine times for each observed angle it was presumed that the effect of this distortion was almost annihilated. Great skill is shown in the apportionment of the errors of observation. In the computation of the triangles, Legendre's method was used; as it appeared to be more exact than the method of referring to the chord triangles (used generally by the English geodists.) The azimuths were determined by observations of Polaris, β Ursæ Minoris, and β Cephei, at their greatest digressions. The meridian arc was calculated by computing separately the intervals between the points where the sides of the triangles (produced if necessary) cut the meridian of Takal Khera. The meridional distance from Daumergidda to Takal Khera, as deduced from the Beder base, was 1,105,618 feet: that deduced from the Takal Khera base 1,105,381. The difference is not explained; Captain Everest has adopted the mean, or 1,105,499 feet. The distance from Takal Khera to Kulliampoor is 1,097,320 feet; and the results from the two bases at its extremities agree almost exactly. The amplitude was found by numerous observations of 24 stars with the zenith-sector used by Colonel Lambton. The extent of the Indian arc has now become so great that it is impossible to observe the same stars at both extremities with the sector, and therefore the absolute latitudes must be calculated from the catalogued places of the stars. Colonel Lambton's observations were therefore recomputed with the improved catalogue, and the united results are: latitude of Punnæ, 8° 9′ 31″.685; of Daumergidda, 18° 3′ 16″.075; of Takal Khera, 21° 5′ 51″.940; and of Kulliampoor, 24° 7′ 11″.851. For details we must refer to Captain Everest's interesting *Account of the Measurement of an Arc of the Meridian between the Parallels of* 18° 3′ *and* 24° 7′

Section 5.—*Measures of Arcs of Parallel.*

Method used in the measure of the arc of parallel across the mouth of the Rhone.

In the verification of the French meridian by Cassini de Thury and Lacaille, the arc of parallel extending from Mont St. Victoire, near Aix, to the meridian of a station near Cette was thus measured. In fig. 37, let P be the pole of the Earth; V, Mont St. Victoire; S, the station near Cette; V*s*, an arc of parallel; C K, H *u*, perpendiculars on P H, P V. By a triangulation founded on a base measured near Arles, and by observation of the azimuth of H at V, with the usual calculations by parallels and perpendiculars, H *u* = 24,710.7 toises, *u* V = 10,422.7; whence the distance of the parallels of H and V = 10,328.3, which, considering 1° = 57,048, corresponds to a difference of latitudes 10′ 52″. The latitude of V being found = 43° 31′ 50″, that of H is found. And the length of H *u* will not sensibly differ from the length of the arc of parallel passing through H; increasing this in the proportion of cos lat. H : cos lat. V, V *k* is found = 24,785.2. Now investigating the convergence of meridians, and applying it to the angle P V H, V H *k* is found; and V H C having been determined by the triangulation, C H *k* and C H P are found. From this angle, and the length of C H, c *k* is found in the same manner as V *k*: it is 33,149.5. By a similar process *c s* = 20,728.9. The sum or V *s* = 78,663.6.

Mea of Ar Paral

It has been explained in Section 3, that the difference of longitude of two places can be found if we have any means of comparing clocks regulated to the solar or sidereal time at those places. The most convenient method is, to observe from both places some instantaneous signal, and to note the time indicated by both clocks at the time of observation. In the present instance, the difference of longitudes was determined by observing from V and S the explosion of ten pounds of gunpowder at a point between them. The duration of the flash was estimated at less than half a second. The clocks were regulated by equal altitudes of the Sun and stars. By a mean of four explosions, on December 14 and 15, 1739, and January 4 and 5, 1740, the difference of longitudes was found to be $7^m\ 33^s\frac{1}{4}$ of time, or 1° 53′ 19″ of arc; whence 1° of parallel in latitude 43° 31′ 50″ = 41,618.

Of the observations for determining the clock errors, (upon which the difference of the longitude wholly depends,) no details are given. The extreme difference of the four determinations, which are quite independent, is 1½ second of time. The result, we imagine, is not subject to any great error, though the omission abovementioned makes it difficult to assert this positively.

Metho used i meas the E arc o rallel.

In the course of the English survey, several arcs of parallel have been measured. The only one which, from its length, appears worthy of confidence, is that between Beachy Head and Dunnose. The difference of longitudes was thus ascertained *geometrically*. Proceeding from the bases measured on Hounslow Heath and Salisbury Plain, by the method of parallels and perpendiculars, and considering the latitude of Greenwich = 51° 28′ 40″, and the length of 1° = 60,851 fathoms, the latitude of Beachy Head was found = 50° 44′ 23″.71. Similarly the latitude of Dunnose was found = 50° 37′ 7″.31. At Beachy Head the azimuth of the signal on Dunnose was found, by observing the angle between it and a staff at a convenient distance, and by observing with the great theodolite, the difference of azimuth of this staff, and the Pole-star at its greatest azimuthal digression. By nine observations the angle between Dunnose and the North meridian was found to be 96° 55′ 58″. Similarly, by seven observations at Dunnose, the angle between Beachy Head and the North meridian was found to be 81° 56′ 53″. The problem now to be solved is this: Given the astronomical latitudes of two stations on a surface (not necessarily spheroidal) differing little from a sphere, and their reciprocal azimuths, to find the difference of longitude, or the inclination of their meridian planes. The following beautiful solution is given by Dalby, and is the foundation of the method used in the English and Indian surveys; the considerations connected with it are almost sufficient for a complete theory of spheroidal triangles.

Diff of lo may foun reci obs of a

In fig. 38, let B and O be two stations sufficiently elevated to be reciprocally visible; O B the straight line described by the rays of light; B R, O S normals, drawn in the direction of gravity; let P R S be that line parallel to the Earth's axis of rotation which cuts both these normals. (There is but one such line, as will easily be seen by supposing the whole figure projected on an equatorial plane; and whether it coincides or not with the axis of rotation is of no consequence.) The azimuth of O as seen at B is the inclination of the planes O B R, P B R; similarly, the azimuth of B as seen from O is the inclination of B O S, P O S. With radius C *p* = 1 construct a sphere, and take two points b, o, whose astronomical latitudes are the same as those of B and O, and whose meridian planes coincide with their meridian planes; that is, let C b and C o be parallel to R B and S O. Now we are to find the relation between the azimuths of o seen from b, and b seen from o, and those of O seen from B, and B seen from O.

From R draw R G parallel to S O, or C o; and from S draw S Q parallel to R B, or C b. Then each of the planes G B R, O Q S, is parallel to $o\,b$ C; and P B R, $p\,b$ C, are the same plane; also P O S, $p\,o$ C, are in the same plane. Consequently, the inclination of the planes P O S, Q O S, is equal to the angle o; and the inclination of P B R, G B R, is equal to the angle at b. Hence the azimuthal angle at O is *less* than that at o by the inclination of the planes B O S, Q O S; and the azimuthal angle at B is *greater* than that at b by the inclination of the planes O B R, G B R. If then the inclination of B O S, Q O S, be equal to the inclination of O B R, G B R, the *sum* of the azimuthal angles at B and O will be equal to the *sum* of those at b and o. We must now discover in what cases those inclinations are equal.

First, they are equal when R coincides with S, as both inclinations then vanish. This happens when the figure is spherical, with any latitudes, or with equal latitudes when the figure is any solid of revolution.

Secondly, from B draw B H perpendicular on O S, and B L perpendicular on the plane Q O S; and from O draw O K perpendicular on B R, and O M perpendicular on the plane G B R. Then the tangent of the inclination of O B R, G B R, is $\frac{\text{O M}}{\text{K M}}$; and the tangent of the inclination of B O S, Q O S, is $\frac{\text{B L}}{\text{H L}}$. The numerators are equal, (as they are the perpendicular distances of two parallel planes at different points;) are the denominators also equal? To discover this, project the figure on the plane G B R, (fig. 39,) then the lines K M, H L will be equal, if O N, B N are equal. This will happen when B O N = O B N, which holds when the reciprocal depressions are equal. Further than this we cannot proceed; but it will easily be seen that O N, B N are very nearly equal in all cases where O and B are equally elevated above a surface whose curvature does not alter very rapidly. If unequally elevated, the error in the assertion (that the inclinations of O B R, G B R, and of B O S, Q O S, are equal) arises only from this circumstance, that a perpendicular to the horizon at O does not appear perpendicular when seen from B; the effect of which, as we mentioned before, is quite insensible. We may therefore assert, that, for all practical purposes, these inclinations are equal; and, consequently, that the sum of the azimuthal angles at B and O is equal to the sum of those at b and o.

The first conclusion that we shall derive from this theorem is, that the spherical excess in a spheroidal triangle is the same as in a spherical triangle, whose vertices have the same astronomical latitudes and the same difference of longitude. In fig. 40, let B O C be a spheroidal triangle, and $b\,o\,c$ the corresponding spherical triangle. Adding the equations

$$\text{POB}+\text{PBO}=pob+pbo,$$

$$\text{PCB}+\text{PBC}=pcb+pbc,$$

Measures of Arcs of Parallel.

we have

$$\text{POB}+\text{PCB}+\text{OBC}=pob+pcb+obc.$$

Subtracting

$$\text{POC}+\text{PCO}\qquad=poc+pco,$$

there remains

$$\text{COB}+\text{OCB}+\text{OBC}=cob+ocb+obo,$$

and, consequently,

$$\text{COB}+\text{OCB}+\text{OBC}-180^\circ=cob+ocb+obc-180^\circ.$$

Theorem for finding the difference of longitude.

We shall next observe, (and this, in fact, is the application for which the theorem was invented,) that any equation relating to the spherical triangle $p\,o\,b$, fig. 38, in which only $p\,o$, $p\,b$, $o\,p\,b$, and $o+b$ are concerned, is equally true if we substitute for them colat. of O, colat. of B, difference of longitudes of O and B, and sum of azimuthal angles at O and B, (these being respectively equal to the former.) Now (Trigonometry, Art. 117.) $\tan\frac{op\,b}{2}=\frac{\cos\frac{p\,b-p\,o}{2}}{\cos\frac{p\,b+p\,o}{2}}\cdot\cot\frac{b+o}{2}$, and therefore $\tan\frac{1}{2}\,\text{diff. longitudes}=\frac{\cos\frac{1}{2}\,\text{diff. latitudes}}{\sin\frac{1}{2}\,\text{sum of latitudes}}\times\cot\frac{1}{2}$ sum of azimuthal angles. This is the theorem to be used for finding the difference of longitudes. An examination of it by the method given in Trigonometry, Art. 161, will make it evident that, in general, a small error in the latitudes produces no sensible error in the determination, while an error in the azimuths is of great importance; but that when the latitudes are small, the errors receive large multipliers in the ultimate result. This method ought not, therefore, to be used for stations near the Equator; and we shall therefore take no notice of the arc of parallel measured by Col. Lambton in India.

Ought not to be used in low latitudes.

From the data given above, the difference of longitude of Beachy Head and Dunnose is found to be 1° 26′ 47″.87; which will not be sensibly altered by the minute alterations since made in the latitudes.

The terrestrial arc of parallel was found by a method equivalent to the following. In fig. 41 let B L, D E be two parallels through B and D; B W and D R perpendiculars to the meridians P B, P D. In the triangles W B D, R B D, the necessary angles being known, and the chord of B D being found by triangulation = 339,397.6 feet, the arc B W was found = 336,119.1, and D R = 336,983.5. Now the latitudes of B and W differ so little that we may suppose their normals to intersect the axis in the same point T, fig. 42; construct a sphere, with centre T, passing through B; then W and L will be nearly in its surface. Then it is easily seen that tan W T B = cos lat. B × tan diff. long.; and $\text{B W}=\text{T B}\times\text{W T B}=\text{T B}\times\frac{\text{W T B}}{\tan\text{W T B}}\times\cos\text{lat. B}$ $\times\tan\text{diff. long.}$ Also the arc of small circle B L = T B × cos lat. B × diff. long.; consequently $\text{B L}=\text{B W}\times\frac{\text{diff. long.}}{\tan\text{diff. long.}}\times\frac{\tan\text{W T B}}{\text{W T B}}$. Now diff. long. = 1° 26′ 47″.87, and W T B = 54′ 56″.21; whence B L is found = 336,076.2. Similarly, D E is found = 336,940.5. These are arcs of parallel corresponding to a difference of longitude of 1° 26′ 47″.87, in latitudes 50° 44′ 23″.7 and 50° 37′ 7″.3; the corresponding lengths of one degree are 232,316.5 and 232,914.0.

It is stated by Captain Kater, (*Phil. Trans.* 1828,) that the theodolite used for determining the azimuth angles at Beachy Head and Dunnose (upon the accuracy of which the value of the result wholly depends) did not admit of adjustment sufficiently exact to give these angles with the necessary precision. Be this as it may, it appears certain (from the description of the mode of observation) that every care was taken to insure all the accuracy that it was possible to obtain. The result of these observations was intended to fix a scale of longitude for the great Map of England; and the observers knowing fully the importance of the determination, appear to have been well satisfied with its accuracy. Whether the error of collimation was corrected does not appear; but in the description of the instrument it is expressly remarked, that the telescope admitted of being reversed for this purpose. The result, however it may disagree with that which we shall next present, must, we imagine, be considered as equally valuable in proportion to the extent of the arc.

Correction of the difference of longitude of Dover and Falmouth by transportation of chronometers.

From the value of an arc of longitude nearly coinciding with those which we have given, (the lengths of 1° of parallel given in the *Trigonometrical Survey* are 38,718 and 38,818 fathoms,) the difference of longitude between Dover and Falmouth was calculated to be $6° 20' 52''.5$, or $25^m 23^s.5$ of time. To determine this independently, Dr. Tiarks was sent by sea with twenty-four chronometers to compare the apparent times at Dover and Falmouth. Three trips were made; the apparent time was determined by equal altitudes; this was compared with the time shown by the chronometers; and thus, the error of the chronometers with regard to each of these apparent times being found, the difference of the Dover and Falmouth time at the same instant was found. The result was that the difference of longitude is $25^m 28^s.4$; and this probably cannot be subject to any great error. This amounts to the same as saying, that an arc in the parallel of Beachy Head (lat. $50° 44' 23''.7$) whose length is 1,474,672 feet, embraces a difference of longitude of $25^m 28^s.4$ of time, or $6° 22' 6''$; or that 1° of parallel = 231,563 feet.

Measure of the arc of parallel from Padua to Marennes.

In the determination of the difference of longitude of two places at a very great distance from each other, and where the transportation of chronometers easily and rapidly cannot be accomplished, the following methods may be used. The difference of longitude may be ascertained by astronomical observations carried on simultaneously at the two extremities; as observations of the Moon's right ascension at the time of her transit; observations of eclipses of Jupiter's satellites, (which are a sort of signals seen at both places at the same absolute time;) and observations of occultations of stars by the Moon, or of solar eclipses, (which differ from the last only in this respect, that the absolute time of the phenomenon is not exactly the same at both places, but that the difference admits of calculation.) The last is the most accurate of all known methods. Or the difference of longitude may be found by dividing the arc into several partial arcs, such that a point comprised in each may be visible at both its extremities, and establishing at each of those extremities a temporary observatory, and then determining the difference of longitude of these extremities by observation of artificial signals as in the French arc; and thus making the whole determination the sum of the several partial and independent determinations. Or instead of making all the determinations independent of each other, and dependent on the correctness of the apparent time used at each of the temporary observatories, the signals may be made at the signal posts, and observed at the temporary observatories, along the whole line in the same evening: then if there be any error in the assumed apparent time at one of the intermediate observatories, it will have the effect of increasing the determined extent in longitude of the arc on one side, and diminishing it for that on the other side, so that their sum will be unaltered. It is only necessary that the rates of the clocks be known pretty accurately. (See Mr. Herschel's Paper, *Phil. Trans.* 1826.) It is found in practice extremely difficult to establish the system of cooperation necessary for this method. In the arc which we are now considering, the second method was generally used, but the principle of the last was introduced in one part of it.

Differe of long of Padu and Mi

In August 1824, signals were made by the explosion of gunpowder on four evenings on the summit of Monte Baldo, a mountain on the East bank of the Lago di Garda. Ten signals were made each evening; the quantity of powder used for each signal was three-quarters of a Viennese pound. They were observed by several astronomers at the observatories of Padua and Milan, (as well as at Bologna, Modena, and Verona.) Their difference of longitude was found to be $10^m 43^s.27$ in time. All the observations are given in the Milan *Ephemeris* for 1826: they appear to have been made with all possible care, and the extreme discordance of the results is little more than a second of time. The difference of longitude of the church of Santa Giustina at Padua, and the cathedral at Milan, was inferred to be $10^m 45^s.38$.

Differe of long of Mil and M Cenis.

In September 1821, ten signals were given on each of three evenings, on the mountain Roche Melon. They were observed at the observatory of Milan, and at a temporary observatory on the plain of Mont Cenis. The error of a chronometer (by Earnshaw) on mean solar time was found from observations with a transit-instrument erected near the hospice, and the chronometer was then carried to the place at which Roche Melon is visible. The difference of longitude was found $= 9^m 0^s.20$; whence the difference of longitude of the cathedral at Milan and the hospice at Mont Cenis $= 9^m 0^s.81$. The details are given in the *Opérations Géodésiques, &c.* It is easily seen that the difficulty of fixing firmly the instruments and other causes render this determination less certain than the last; but it appears to be satisfactory.

Differ of lon of Mo Cenis Genev

In September 1822, observations were made for the purpose of finding the difference of longitude of Mont Cenis and Mont Colombier, a hill on the right bank of the Rhone below Geneva. At Mont Cenis it was found necessary to carry Earnshaw's chronometer to a point 2000 feet above the observatory. The chronometer was compared, before going and after returning, with the transit clock; it was also compared when at the place of observation by secondary signals seen there and at the observatory. The results were different: the mean was generally taken. The tempestuous state of the weather made the determination of the absolute time at Mont Colombier very uncertain, and the following arrangement was therefore made. On some of the evenings on which signals made on Mont Tabor were observed at Mont Cenis and the observatory on Mont Colombier, signals were also made on another part of Mont Colombier, and observed at the observatory of Mont Colombier and that of Geneva. Consequently (as we have already explained) the difference of longitude between Mont Cenis and Geneva was found, unaffected by any error in the absolute time at Mont Colombier. The mean of the results from twelve signals (six on September 5, and six on September 7) was $3^m\ 8^s.76$. As this is affected by the errors attending four observations of signals, and as the number of signals is small, this determination cannot be considered equal to the last.

In precisely the same manner, and at the same time, the difference of longitude of Geneva and Solignat was found. Signals made on Pierre-sur-autre were observed at Solignat and Colombier, and signals on another part of Colombier were observed on Colombier and at Geneva. The time at Solignat was determined by absolute zenith distances of stars observed with repeating-circles. The mean of the results of twelve signals on September 6 and 7, was $11^m\ 53^s.97$. See *Conn. des Temps*, 1828. This is liable to the same objections as the last; but if combined with the last, the result will be almost free from any error in the absolute time at Geneva. The difference of longitude of Geneva and the station on the Puy d'Isson (near Solignat) was inferred to be $11^m\ 57^s.82$.

If the signals on September 7 were thought sufficiently numerous, there would be no necessity for using the observations made at Geneva. On that evening the difference of longitude of Mont Cenis and Colombier was found to be $4^m\ 44^s.28$, and that of Colombier and Solignat $10^m\ 18^s.81$, whence that of Mont Cenis and Solignat $= 15^m\ 3^s.09$, and that of Mont Cenis and Puy d'Isson $15^m\ 6^s.94$, unaffected by the error of absolute time on Colombier.

In August 1823, the difference of longitude of Solignat and La Jonchère was determined by twenty signals on the Mont d'Or. The mean was $6^m\ 49^s.99$; from which the difference of longitude of the Puy d'Isson and Sauvagnac (near La Jonchère) $= 6^m\ 51^s.39$. Signals were, in fact, made on three evenings; but the results given by the first evening's observations differ steadily two seconds from those of the other evenings. No explanation of this anomaly could be given, and the results of the first evening's observations were rejected. This circumstance seems to throw some doubt upon the conclusion adopted. The absolute times were determined from zenith distances of stars.

In September 1823, the difference of longitude of La Jonchere and St. Preuil, was found in the same way from ten signals on September 20, given on Puy-Cogneux. Though signals were given on eight evenings it was only possible (from some atmospheric cause) to see them on one. M. Nicollet considers, however, that the favourable circumstances under which these observations were made leave no doubt of the accuracy of the result. The difference of longitude of La Jonchère and St. Preuil appeared to be $6^m\ 28^s.34$; that of Sauvagnac and St. Preuil, $6^m\ 23^s.09$.

In October 1823, similar observations were made at St. Preuil and Marennes. The mean of forty-six signals gave for the difference of longitude $3^m\ 49^s.01$; and between St. Preuil and the steeple of Marennes, $3^m\ 48^s.99$.

Determination of Figure of Earth from Geodetic Measures.

Adding together these differences, we find for the difference of longitude between the steeple of St. Giuslina at Padua, and the steeple of Marennes, $51^m\ 56^s.25$, or 12° 59′ 3″.75. The terrestrial length of the corresponding arc of parallel in latitude 45° 43′ 12″, as found from the French and Piedmontese survey, (we know not by what method of calculation,) is 1,010,996 mètres.

Value of this determination.

It is difficult to estimate the value of this determination. We are not, ourselves, inclined to rate it very high. Of the accuracy of the determinations on the Italian side of the Alps there can be little doubt. The credit of the Mont Cenis observations rests entirely on the steadiness of rate of a single chronometer, which was every day carried on a mountain path to a considerable elevation. Of the French determinations it seems probable that one (if not two) is liable to considerable errors. Those who know practically the difficulty of determining the time at a fixed observatory, and with the best instruments, to an accuracy of one-tenth of a second, will probably allow that there may have been at any of the temporary stations an error of a quarter of a second of time in the correction of the clock. When to this are added the errors of chronometers, and of observations of signals, and the doubt which is thrown on some parts by large and unexplained discrepancies, and when it is considered that the determinations of the six partial arcs are absolutely independent; we cannot flatter ourselves that the difference of longitude of the extreme points is determined within one second of time. And the principal observers were themselves so sensible of this uncertainty that they had (we believe) concerted a plan for the immediate determination of the difference of longitude of Marennes and Padua, by occultations or other astronomical phenomena observed at both places. The respective governments (as we are informed) refused to defray the expenses, on the ground that the arc might in a short time be extended further to the East. It is much to be regretted that the accurate determination of the extensive arc already surveyed should in the mean time be withheld from the scientific world.

Section 6.—Determination of the Figure of the Earth, from the Geodetic Measures.

Abstract of elements of all the arcs.

The following Table contains an abstract of the elements of the arcs above described. The foreign measures are reduced by supposing the toise = 6.394596 English feet,* (according to Shuckburgh's standard,) and the mètre = 3.280899 English feet.

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* This number is deduced from Captain Kater's measure of the mètre, (*Phil. Trans.* 1818,) supposing the mètre = 443,296 lines of the toise of Peru. The comparison mentioned in the *Phil. Trans.* 1768, allowing for the difference between the Royal Society's standard and Shuckburgh's standard as determined by Captain Kater, (*Phil. Trans.* 1821,) gives for the length of the toise 6.394743 feet of Shuckburgh's standard. Boscovich's arc has been corrected for the quantity (.03413 line) by which Mairan's toise was found to be shorter than the toise of Peru. (*Base du Système Métrique*, tom. iii. p. 414.) The English arcs of parallel, as well as the other English arcs, are reduced to Shuckburgh's standard.

Arcs of Meridian.

No.	Description.	Latitude of Middle Point.	Amplitude.	Length in English feet.	Remarks.
1	Peruvian arc as calculated by Delambre	−1°31′ 0″	3° 7′ 3″.1	1131057	Mountainous country. The amplitude probably well determined.
2	Maupertuis's Swedish arc.	66 19 37	0 57 30.4	351832	Mountainous country. A very little doubt about the amplitude.
3	French arc by Lacaille and Cassini de Thury......	46 52 2	8 20 0.3	3040605	Apparently very good.
4	Roman arc by Boscovich .	42 59	2 9 47	787919	Mountains in the middle of the arc, and sea at both extremities. The determination appears a good one.
5	Lacaille's arc near the Cape of Good Hope	−33 18 30	1 13 17.5	445506	Mountains in the neighbourhood. The determination appears good.
6	American arc by Mason and Dixon	39 12	1 28 45.0	538100	The country favourable; and apparently no doubt about the result.
7	French arc from Formentera to Dunkirk.......	44 51 2	12 22 12.6	4509402	The latitudes depend on inadequate observations with repeating-circles.
8	Svanberg's Swedish arc....	66 20 10	1 37 19.3	593278	Mountainous country. The latitudes doubtful, as in the last arc.
9	English arc from Dunnose to Burleigh Moor......	52 35 45	3 57 13.1	1442953	Excellent.
10	Lambton's first Indian arc.	12 32 21	1 34 56.4	574368	Excellent.
11	Lambton's second Indian arc, as extended by Everest................	16 8 22	15 57 40.2	5794599	Excellent.
12	Piedmontese arc by Plana and Carlini...........	44 57 30	1 7 31.1	414657	The determination excellent. Mountains at both extremities.
13	Hanoverian arc by Gauss .	52 32 17	2 0 57.4	736426	Excellent, subject only to a small doubt about the standard.
14	Russian arc by Struve	58 17 37	3 35 5.2	1309742	Excellent.

Arcs of Parallel.

No.	Description.	Latitude.	Extent in Longitude.	Length in English feet.	Remarks.
15	Arc across the mouth of the Rhone, by Lacaille and Cassini de Thury	43°31′50″	1°53′19″	503022	Pretty good.
16	Roy's arc between Beachy Head and Dunnose	50 44 24	1 26 47.9	336099	Apparently very good.
17	Arc from Dover to Falmouth...............	50 44 24	6 22 6	1474775	Apparently good.
18	Arc from Padua to Marennes	45 43 12	12 59 3.8	3316976	Subject to the accumulated errors of six independent determinations in difficult circumstances.

Equations of the arcs.

Forming for each of the meridional arcs the equation of p. 194, line 22, and for each of the arcs of parallel the expression of p. 193, line 42, we obtain the following Table.

No.	Equations.
1	$b \times .0544111 - be \times .05426 = 1131057$
2	$b \times .0167280 + be \times .02536 = 851832$
3	$b \times .1454455 + be \times .08688 = 3040605$
4	$b \times .0377524 + be \times .01489 = 787919$
5	$b \times .0213197 - be \times .00203 = 445506$
6	$b \times .0258163 + be \times .00512 = 538100$
7	$b \times .2159001 + be \times .10627 = 4509402$
8	$b \times .0283097 + be \times .04293 = 593278$
9	$b \times .0690040 + be \times .06160 = 1442953$
10	$b \times .0276169 - be \times .02371 = 574368$
11	$b \times .2785749 - be \times .20944 = 5794599$
12	$b \times .0196403 + be \times .00978 = 414657$
13	$b \times .0351849 + be \times .03132 = 736426$
14	$b \times .0625662 + be \times .07326 = 1309742$
15	$b \times .0238980 + be \times .03523 = 503022$
16	$b \times .0159783 + be \times .02556 = 336099$
17	$b \times .0703392 + be \times .11251 = 1474775$
18	$b \times .1582185 + be \times .23931 = 3316976$

We shall now proceed to discuss these equations.

1. Comparing the longest arcs, Nos. 7 and 11, we find $b = 20852460$, $e = .003818$.

2. Comparing No. 7 and No. 2, $b = 20816330$, and $e = .006850$.

3. Comparing No. 7 and No. 8, $b = 20851450$, and $e = .003418$.

4. As there is some doubt about both the Swedish arcs, (Nos. 2 and 8,) take the sum of the equations corresponding to them, and compare this with the equation of No. 7. Thus we find $b = 20838100$, and $e = .004722$.

5. The comparison of No. 1 and No. 3 gives $b = 20861200$, and $e = .008558$. The comparison of No. 1 and No. 7, gives $b = 20853720$, and $e = .003196$. This is nearly the same comparison as that from which the French determined the length of their mètre.

6. As the Roman and Piedmontese arcs (Nos. 4 and 12) are in circumstances of locality opposite in character, we may perhaps take the sum of their equations to represent nearly the equation which would be given by an arc in circumstances unaffected by these

peculiarities. Comparing this sum with No. 11 we have $b = 20897940$, $e = .006180$.

7. Comparing No. 11 with the sum of Nos. 9, 13, and 14, we find $b = 20853650$, $e = .003367$.

8. The comparison of the two American arcs (No. 1 and No. 6) gives $b = 20834100$, $e = .002283$.

9. The comparison of Nos. 5 and 11 gives $b = 20910300$, $e = .006961$.

The discordance of these results, especially in the values which they give for the ellipticity, seems to show that several of the measures are affected with some considerable cause of error. This supposition at least is necessary if we suppose the Earth's Figure (at the level of the sea) to be one of revolution, and the generating curve to be at all similar to an ellipse. The most probable disturbing cause is the attraction of mountains; and it will be seen above, that the greatest discordances exist in those comparisons in which Nos. 2, 4, 5, and 12 are used; all of which are in mountainous Countries. Let us then exclude all which are in that predicament, namely, Nos. 1, 2, 4, 5, 8, and 12, and with the others endeavour to ascertain the Earth's dimensions.

10. Comparing the sum* of Nos. 3, 6, 7, 9, 13, 14 with the sum of Nos. 10, 11, we find $b = 20854270$, $e = .0033808$.

11. If we confine ourselves to the modern arcs, we may compare the sum of Nos. 7, 9, 13, 14 with the sum of Nos. 10, 11, and we get $b = 20853355$, $e = .0033232$.

The mean of the two last may, perhaps, be considered a good determination. (This amounts to the same as giving the modern arcs double the credit, *cæteris paribus*, of the ancient arcs.) Thus we find $b = 20853810$ feet, $e = .0033520$.

Substituting these values in each of the equations of meridian arcs, we get the following apparent errors. These may be produced by errors in the geodetic measures, or by errors in the astronomical determination of amplitude.

No.	Latitude of Middle Point.			Calculated Length.	Measured Length.	Error in Measure.	Correspond-ing Error in Amplitude.
1	−1°	31′	0″	1130886	1131057	+171	−1″.7
2	66	19	37	350615	351832	+1217	−12.0
3	46	52	2	3039166	3040605	+1439	−14.2
4	42	59		788322	787919	−403	+4.0
5	−33	18	30	444456	445506	+1051	−10.4
6	39	12		538726	538100	−626	+6.2
7	44	51	2	4509768	4509402	−366	+3.6
8	66	20	10	593366	593278	−88	+0.9
9	52	35	45	1443302	1442953	−349	+3.4
10	12	32	21	574260	574368	+108	−1.1
11	16	8	22	5794708	5794599	−109	+1.1
12	44	57	30	410259	414657	+4398	−43.4
13	52	32	17	735929	736426	+497	−4.9
14	58	17	37	1309865	1309742	−123	+1.2

The reader is now able to judge whether the dimensions which we have used, or any others, are likely to represent with tolerable accuracy the measured lengths of meridian arcs on the Earth's surface. We have sometimes thought that the measured arcs appeared too small, or the amplitudes too great, in middle latitudes; or that the comparison of equatorial arcs with those in middle latitudes gave a smaller ellipticity than that of arcs in middle latitudes with Northern arcs. These indications would show (see Section 3) that the Earth's Figure is protuberant at middle latitudes above the elliptic spheroid. But after careful examination we believe that there is no unequivocal appearance of this And we do not perceive, that the difference between the calculated and the measured arcs would be materially diminished (at least for the best arcs) by adopting a different value for the ellipticity. And observing that Nos. 1 and 6 are nearly in the same longitude, that Nos. 2, 3, 4, 5, 7, 8, 9, 12, 13, 14, are nearly in the same longitude 90° from the former, and that Nos. 10 and 11 are in a third longitude 60° from the last, we think ourselves entitled to conclude that there is no important difference between the different meridians of the Earth.

Determination of Figure of Earth from Geodetic Measures.

On the whole we are inclined to think, that as far as meridian measures go, the Earth's form may be very well represented by that of an ellipsoid of revolution with the dimensions that we have assigned. The greatest differences are at the places and in the directions that we should *à priori* have expected. No. 12 is measured across the great basin of Piedmont and absolutely abuts on the feet of very lofty mountains at both extremities; No. 3 is terminated by the Pyrenees;* No. 5 is in circumstances partly similar to those of No. 12; and No. 2 is in a mountainous country. The other differences are not greater than such as might be produced by a small lump of unequal density below the Earth's surface, or (as Captain Everest has shown in his *Account of the Measurement, &c.*) by a mountain range at a considerable distance.

The assumed dimensions satisfy the arcs of meridian.

We shall now proceed to consider the arcs of parallel.

Discussion of arcs of parallel.

12. Comparing No. 17 with No. 9, $b = 20841200$, $e = .003763$. These then are the dimensions of the ellipsoid that corresponds most exactly to the curvature of England.

13. Comparing No. 18 with No. 11, $b = 20855220$, $e = .003466$.

14. Comparing No. 18 with No. 7, $b = 20848880$, $e = .003667$.

Here we may observe that upon comparing an arc of parallel nearly in latitude 45°, with two arcs of meridian of which one is in a low latitude, and the other

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* In determining elements from a number of observations or measures, the method of *minimum squares* has frequently been used. We have rejected the use of this method, for the following reason. It is perfectly certain, that the elements determined by this method, if substituted in the equations of condition, will generally give the greatest apparent errors of linear measure in the smallest arcs, and *vice versâ*. A consequence so directly opposed to common sense cannot, we think, be supported by any symbolical reasoning. The doctrine of chances (from which this method is deduced) is more liable than any other to errors of omission in the preliminary considerations for the solution of any problem; and we prefer resting in the belief that there is some such error in the proof of this method, to receiving the consequence abovementioned. We have, therefore, thought best to use the method commonly employed in Astronomy, *viz.* to take the sum of groups of the equations of condition, and to consider each sum as one equation: the groups being selected so as to make the coefficient of e large and positive in one sum, and large and negative in the other.

* A part of this error is undoubtedly to be attributed to the errors of bases, &c. mentioned by Delambre, *Base du Système Métrique*, tom. iii. p. 163. Perhaps a small part of his differences is to be assigned to the later measure.

nearly in latitude 45°, the first comparison gives a smaller ellipticity than the second. This, as we have mentioned in page 197, would indicate that the Earth's Figure projected at middle latitudes above the spheroidal form. But we place little reliance on this conclusion, because the determination of the extent in longitude of the arc of parallel does not appear to us sufficiently certain.

Comparison of calculated and measured arcs of parallel.

If we substitute the values $b = 20853810$, $e =$ 0033520, in the equations of arcs of parallel, we get the following apparent errors.

No.	Latitude.	Calculated Length.	Measured Length.	Error in Measure.	Error in Amplitude.		Lateral Deviation of Plumb-line.
					In Space.	In Time.	
15	43°31′50″	500827	503022	+2195	−30″.0	−2ˢ.00	21″.7
16	50 44 24	334995	336099	+1104	−17.2	−1.15	10.9
17	50 44 24	1474705	1474775	+70	−1.1	−0.07	0.7
18	45 43 12	3316187	3316976	+789	−11.1	−0.74	7.8

The assumed dimensions satisfy the arcs of parallel.

The magnitude of these errors, and the fact of their all having the same sign, appear at first sight rather alarming. It must, however, be remarked, that the two first arcs are measured across low land or sea, and terminated at both extremities by hills, and the effect of the attraction of the hills would be to make the amplitude smaller than if no such inequality existed. The extremities of the third and fourth arcs are more favourably situated; and in these the errors are within the limits of errors of observation. On the whole we are pretty well satisfied with the agreement between the computed and measured arcs.

Conclusion deduced from the measures of arcs.

The following are our conclusions from the discussion of the measures.

1. The measured arcs may be represented nearly enough *on the whole* by supposing the Earth's surface (at the level of the sea, or at the level at which water communicating freely with the sea would stand) to be an ellipsoid of revolution, whose polar semiaxis is 20,853,810 English feet, or 3949.585 miles, and whose equatorial radius is 20,923,713 feet, or 3962.824 miles. The ratio of the axes is 298.33 : 299.33; and the ellipticity (measured by the quotient of the difference of the axes by the smaller) is $\frac{1}{298.33}$, or .003352. The meridional quadrant is 32,811,980 feet.

2. In order, however, to conciliate the various measures with this assumed form, it is necessary to suppose that in some observations, made apparently with the greatest care and with competent instruments, the latitude is erroneous to the amount of at least 22 seconds. But these errors occur almost without exception in the localities where we should have expected them (on the principle of universal gravitation) from the disturbance of the adjacent mountains.

3. It is necessary also to suppose that in some cases the direction of gravity is altered to the East or West of that which it would have, were the Earth's Figure perfectly regular. These instances also occur in localities where (as above) we might *à priori* have expected them.

4. In consequence of these discordancies, the dimensions above given are liable to some uncertainty. We are, however, inclined to think that e cannot be so small as .00325, nor so great as .00345.

Obser tions Pendul

5. It appears (see Section 2, Art. 12 and 33) that if the whole attraction were directed to the Earth's centre, the ellipticity would be $\frac{1}{580}$; if the Earth were homogeneous, and the particles mutually attracted each other, the ellipticity would be $\frac{1}{230}$. The ellipticity given by the measures is between these. We are entitled then to suppose that the state of the Earth is intermediate to these two states: that is, to suppose that the interior of the Earth is more dense than the surface, but that the mutual attraction of the parts near the surface is sensible when compared with the attraction exerted by the parts near the centre.

Section 7.—Observations of Pendulums, for the purpose of measuring the Force of Gravity.

Neces for usi pendul

The necessity of using the pendulum for measuring the force of gravity, will easily be seen if we consider the impossibility of ascertaining the magnitude of that force by any experiments on *single* descents of free masses. The quantity to be measured is the velocity which gravity creates in any freely descending body by its action continued during one second (or any other given duration) of time. This will be known, if we determine the space through which gravity draws the body in that time. But with all the contrivances that we can use for retarding the motion in a known proportion so as to make it measurable to our senses, it is impossible to make the measure of the space sufficiently accurate. Any one who has seen experiments with Atwood's or Smeaton's apparatus will allow that we cannot expect to measure the space described within a hundredth part of the whole. With the pendulum we can ascertain the same thing (in the opinion of some philosophers) within a four-hundred-thousandth part of the whole. This accuracy arises partly from the circumstance that the experiments with the pendulum may be continued for a very long time, with the certainty that there is no interruption between the end of one vibration and the beginning of the next, and partly from the very remarkable fact that the friction and other disturbing causes which ultimately put a stop to the experiment, (and which in the case of a descending body in Atwood's and other apparatus, would completely alter the results even if we had the power of observing them accurately,) do not injure its accuracy as long as it lasts.* We shall now proceed to describe the general principle, and the most approved methods of deducing the magnitude of gravity from observations of the pendulum.

Gen prin the the dulu

In our Treatise on Mechanics, § XV. it is shown that the time of vibration (expressed in seconds) of a simple pendulum whose length is l, in double the circular arc whose versed sine to that radius is b, will be nearly expressed by $\pi\sqrt{\frac{l}{2g}} \times \left(1 + \frac{b}{8l}\right)$, where g equals the space through which a body would fall freely in a second of time; the arc being supposed small. If the arc be extremely small the time will not differ

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* For a demonstration of this we must beg to refer to the *Cambridge Transactions*, vol. iii. p. 111, &c.

much from $\pi\sqrt{\frac{l}{2g}}$. Suppose such a length to be given to the pendulum that the time of vibration may be one second. Then $\pi\sqrt{\frac{l}{2g}} = 1$, or $g = \frac{\pi^2 l}{2}$. The space g then will be found by multiplying the length of the pendulum by $\frac{\pi^2}{2}$. And if gravity is not the same on different parts of the Earth, the length proper for making the time of vibration equal to one second will not be the same in all. But when the lengths at the different places are determined, the proportion of the forces of gravity at those places (measuring the forces by the spaces through which bodies would fall freely in one second) will be the same as the proportion of these lengths.

Different places the seconds' pendulum has different lengths.

Found by observing the time of vibration of a given pendulum.

But it is seldom in our power to make a pendulum which shall vibrate exactly in one second. Instead of this we observe the time in which a pendulum of known length vibrates. Now, it is easily seen from the expression $t = \pi\sqrt{\frac{l}{2g}}$, or $l = \frac{2g \, . \, t^2}{\pi^2}$, where t is the time of vibration, that the length of the pendulum at the same place is proportional to the square of its time of vibration. The length of the seconds' pendulum then bears to the known length the same ratio as unity to the square of the number of seconds in the observed time of vibration.

Compound pendulum may be used as well as simple pendulum.

All this, however, supposes the pendulum to be a material point suspended by a string without weight; a construction which evidently is imaginary. But it is shown in **Mechanics**, § XX., that if a compound pendulum be given, we may calculate the length of a simple pendulum which would vibrate in the same time, whatever be the magnitude of gravity. A pendulum, therefore, such as may be made in practice, may be used in all respects for the same purposes as the imaginary simple pendulum.

Method of transporting an invariable pendulum to different places.

The method which we have described, is in fact that which has been adopted in many of the most important experiments. The absolute length of the seconds' pendulum is thus determined afresh at every station of observation. But a method has also been used of finding the proportion between the force of gravity at each place, and the force of gravity at some place (London for instance, or Paris) where its absolute magnitude has been well ascertained. This is done by transporting the same pendulum, after having observed it at the place of reference, to all the different stations, and observing the time of vibration at all. Then, since $g = \frac{\pi^2 l}{2 t^2}$, and l is the same at all the observations, (the pendulum being invariable,) g is inversely proportional to t^2. Consequently, the force of gravity at any new station, is to the force of gravity at the place of reference, inversely, as the square of the time of vibration at the new station to the square of the time of the same pendulum's vibration at the place of reference; or directly, as the square of the number of vibrations per day at the new station to the number of vibrations per day at the place of reference. The lengths of the seconds' pendulums are in the same ratio; consequently, that at the place of reference being known, that at the new station is found.

Observations of Pendulums.

We shall now mention some additional considerations which must in all operations of great accuracy be taken into account.

Correction for the length of the arc of vibration.

First, we have supposed the arcs of vibration to be indefinitely small. When the arc is supposed small, but not so small that the term depending on it can be wholly neglected, the time of vibration is nearly $\pi\sqrt{\frac{l}{2g}} \, . \left(1 + \frac{b}{8l}\right)$. If the arc of vibration be n degrees on each side of the vertical, then

$$b = l \, . \, \text{versin.} \, n^\circ = 2l \, . \sin^2 \frac{n^\circ}{2} = l \, . \, \frac{n^2 \sin^2 1^\circ}{2},$$

(nearly,) and the time of vibration is nearly

$$\pi\sqrt{\frac{l}{2g}} \, . \left(1 + n^2 . \frac{\sin^2 1^\circ}{16}\right).$$

This is the time observed; and if the observations continue for so short a time that n does not sensibly alter, the observed time of vibration ought to be divided by $1 + n^2 . \frac{\sin^2 1^\circ}{16}$, or the number of vibrations per day ought to be multiplied by the same quantity, in order to represent the time or number of vibrations in indefinitely small arcs, (to which alone all our reasoning above will apply.) But if the observations continue for a long time it is necessary to know what is the law of decrease of the arc. The laws of friction and resistance of the air for small velocities being little known, it is best to recur to direct experiment. It was found by Borda (and we have found the same by our own observations) that the decreasing arcs form very nearly a geometrical series.* Putting m for the number of vibrations observed, (m being a large number,) p for the proportion of each arc to the preceding arc, (where $1 - p$ is extremely small,) n' for the number of degrees in the last arc $= n \, . \, p^{m-1}$, the degrees of the successive arcs are n, $n p$, $n p^2$, &c. ... $n p^{m-1}$, and the sum of all the times of vibration

$$\pi\sqrt{\frac{l}{2g}} \times \left\{m + \frac{n^2 . \sin^2 1^\circ}{16}\left(1 + p^2 + p^4 + \&c. . + p^{2m-2}\right)\right\}.$$

The sum of the geometrical series is

$$\frac{1 - p^{2m}}{1 - p^2} = \frac{1 - p^{2m-2}}{1 - p^2} \text{ very nearly;}$$

hence the sum of all the times

$$= \pi\sqrt{\frac{l}{2g}} \times \left\{m + \frac{n^2 - n'^2}{1 - p^2} \, . \, \frac{\sin^2 1^\circ}{16}\right\}.$$

But $p^{m-1} = \frac{n'}{n}$, therefore $p^2 = \left(\frac{n'}{n}\right)^{\frac{2}{m-1}} = \left(\frac{n'}{n}\right)^{\frac{2}{m}}$ very nearly, therefore $\log p^2 = \frac{2}{m} (\log n' - \log n)$. But $\log p^2 = \text{modulus} \times \overline{p^2 - 1}$ nearly (as $p^2 - 1$ is very small;) hence $1 - p^2 = \frac{2}{\text{modulus} \times m} \, . \, (\log n - \log n')$; consequently the sum of all the times

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* In our experiments the decrease of the arc at first was a very little more rapid than according to the geometric law, and at last a very little slower.

$$= \pi\sqrt{\frac{l}{2g}} \times \left\{m + m \cdot \frac{\text{modulus} \times (n^2 - n'^2)}{\log n - \log n'} \cdot \frac{\sin^2 1^\circ}{32}\right\};$$

and the mean of the observed times

$$= \pi\sqrt{\frac{l}{2g}} \times \left\{1 + \frac{\text{modulus} \times (n^2 - n'^2)}{\log n - \log n'} \cdot \frac{\sin^2 1^\circ}{32}\right\}.$$

The quantity within the brackets is that by which the observed mean time of vibration ought to be divided, or the number of vibrations per day ought to be multiplied, in order to reduce the vibrations to vibrations in indefinitely small arcs.

Correction for the temperature.

Secondly, we have supposed the length of the pendulum to continue invariable. But a metallic wire or metallic bar undergoes considerable changes in its length from changes in temperature, and it is necessary, therefore, to reduce the number of vibrations to the number which would have been made if the pendulum had been at some standard temperature. Suppose by heat the pendulum's length is increased above that at the standard temperature in the ratio of $1 : 1 + y$ (y being very small:) then the time of vibration is increased in the ratio of $1 : \sqrt{1 + y}$, or $1 : 1 + \frac{y}{2}$ nearly, and the number of vibrations per day is diminished in that ratio. Consequently, the observed number of vibrations ought to be increased in that ratio in order to find the number which would have been made if the pendulum had been at the standard temperature. If the temperature during the observation be lower than the standard temperature, the observed number of vibrations ought to be diminished.

Correction for the weight of the air.

Thirdly, the vibrations have generally been observed in air. But the state of the air being variable, it is desirable to calculate the number of oscillations which would have been made in vacuum, all other circumstances being the same. For this we have only to observe that the effect of the air (like that of any other fluid upon a body immersed in it) is to diminish the weight of the pendulum by a quantity equal to the weight of the air displaced, or to diminish the apparent force of gravity in the same proportion.* If this diminution be in the ratio of $1 : 1 - z$, then the time of vibration (as will appear by changing g into $g(1 - z)$ in the expressions above) will be increased in the ratio of $1 : \frac{1}{\sqrt{1 - z}}$, and consequently, the number of vibrations per day diminished in the ratio of $1 : \sqrt{1 - z}$, or $1 : 1 - \frac{z}{2}$ nearly. These are the vibrations observed; and therefore to get the number of vibrations in vacuum we must increase the observed number in the ratio of $1 : 1 + \frac{z}{2}$. As the weight of the air is nearly proportional to the height of the barometer, it is necessary for the calculation of this correction to observe the barometer.

We shall now describe some of the practical methods of observing the vibrations of the pendulum.

Obser
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In a few instances the pendulum of a clock has itself been used as an invariable pendulum to be transported from one station to another. This is the simplest of all methods, as the clock may be used as a transit clock, and its rate immediately determined by transits of the fixed stars: at all events comparison with another clock is all that is necessary. And though the accuracy is undoubtedly not so great as with the apparatus that we shall presently describe, yet very valuable results may be obtained in this manner. If the escapement is so constructed that the pendulum receives the impulse of the wheels when it is at the middle of its vibration, (which is nearly the case in the dead-beat construction,) the time of vibration is not altered by the maintaining power. The suspension of the pendulum is a matter of some difficulty. If it be suspended by a spring in the usual way, the time of vibration is not the same and does not vary in the same manner as the time of vibration in a circular arc, and the elasticity of the spring varies with variations of temperature. If it be suspended on knife-edges, (this is the term commonly used for a prismatic bar of very hard steel, on one edge of which, having an angle of from 20° to 90°, the pendulum turns during its vibration,) there is, perhaps, some fear of the edge slipping on its supports when it receives the pressure of the wheel-work. Satisfactory results have, however, been obtained with this construction.

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The method commonly used in the beginning of the last century was to suspend a small weight (commonly in the shape of two frustra of cones with their bases in contact) by a fibre of *pite*, (a preparation, we believe, of the leaf of a species of aloe,) and placing it before a clock to observe the number of vibrations which it made, not by counting them, but by observing when it had gained or lost two vibrations upon the clock pendulum. The clock was thus used to count the great number of vibrations; the observer counted only those which the detached pendulum gained or lost upon it. The number of vibrations which it would have gained or lost in a day being found by proportion, and the number of vibrations per day of the clock pendulum being ascertained by observations of the stars, the number of vibrations of the detached pendulum per day is found. From this, by the application of the corrections above-mentioned, the number of vibrations per day in indefinitely small arcs and in vacuum is found. The length of the pendulum was found by measuring the distance between the lower edge of the forceps that held the thread and the upper surface of the weight; or between the lower edge of the forceps and a plane on which the bottom of the weight would just rest. It is to be remarked, that the length of the seconds' pendulum thus found is always too great, as the curvature of the thread does not begin close to the suspending forceps.

Bord
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The method which was first used by the French, nearly at the time of measuring the arc between Dunkirk and Barcelona, was the following. A spherical ball of platinum, and a brass cap covering about one-fifth of its surface (represented in fig. 43) were ground together so as to fit accurately in every position of the ball. When this is the case, if the cap be suspended the ball will adhere to it provided a very small quantity of grease be interposed. The peculiar advantage sought in this construction was to destroy the effects of unequal Specific Gravity in different parts of the ball

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* We shall speak hereafter of an alteration which it has been found necessary to make in this proportion.

ure of Earth.

by altering its position with regard to the direction of gravity. A fine metallic wire was attached to the cap and fastened at the top to a small apparatus connected with a knife-edge. (See fig. 44.) The upper part of this was a stalk cut with a screw-thread on which a small weight could be adjusted. The time of vibration of the pendulum being known very nearly before the observations were begun, the weight was adjusted so that the small apparatus of fig. 44, without the wire, would vibrate on the knife-edge in that time. Consequently, when the wire, cap, and ball were attached to it, the suspending apparatus might be wholly neglected in the calculation of the length of the equivalent simple pendulum. The knife-edge rested upon a steel plate. The number of vibrations per day was ascertained in the same way as in the first method: a shade with a vertical edge being placed so that when the pendulum was at rest, the vertical edge, as viewed in a small telescope, coincided with the pendulum wire. A cross was made on the bob of the clock pendulum, and the observation consisted in noting when the wire and cross disappeared at the same time behind the edge. All the corrections were applied which we have described. The length was measured by screwing up from below a horizontal plate of steel till it just touched the ball; then the pendulum being removed, a bar of known length with a T head (to the lower surface of which the end of the bar had been accurately fitted) was placed in such a manner that the lower surface of the T head rested on the upper steel plate, and a graduated slider on the bar was then made to touch the lower steel-plate. The ball was placed on the steel-plate and the same slider was used to determine its diameter; the wire and cap were weighed; then to determine the length of the isochronous simple pendulum, a formula was used founded on that given in MECHANICS, § XX. At every station of observation it was necessary to repeat the whole of this process.

The process used by Captain Kater for determining the length of the seconds' pendulum at London (for fixing the standard of English measures) was the following. The pendulum consisted of a bar A B of plate brass, (fig. 45,) about $1\frac{1}{2}$ inch broad, and $\frac{1}{8}$ inch thick. At A was a knife-edge of the hardest steel, its back bearing firmly against solid knees of brass; and at B a similar knife-edge. When the pendulum was in use, these edges rested on horizontal plates of agate. At C was a large flat bob, and at D and E two small slips or tails, the use of which we shall mention hereafter. At F was an adjustible weight, and at G a smaller weight, which by means of a screw could be adjusted with very great nicety. The principle of the operation was to observe the number of vibrations per day made by the pendulum when suspended on the knife-edge A, and again when suspended on B. If these were not equal, the sliding weights F and G were moved till they became equal. Then as A and B were at different distances from the centre of gravity, it was certain (see MECHANICS, § XX.) that B was the centre of oscillation corresponding to the centre of suspension A, and therefore, that the distance between A and B was the length of the simple pendulum vibrating in the same time. The distance between the knife-edges was compared with the distance of two divisions on the standard scale by a microscopic apparatus furnished with internal micrometers.

Observations of Pendulums.

The number of vibrations per day was determined by observing in the following manner the difference between the vibrations of the detached pendulum, and the vibrations of a clock pendulum. Suppose the pendulum suspended on the edge A. On the bob of the clock pendulum, which had been blackened, was placed a circle or lenticular figure of white paper, whose breadth was nearly equal to the breadth of the tail D. Between the two pendulums, or (which was the original construction) in the field bar of the telescope with which they were viewed, was placed an adjustible diaphragm, consisting of two perpendicular cheeks, which were placed at such a distance that they appeared to touch the edges of the tail D when the pendulum was at rest. Now suppose both pendulums to vibrate, the detached pendulum vibrating more slowly than the clock pendulum. The tail D is seen to cross the opening of the diaphragm, and is followed by the white patch on the clock pendulum. At every succeeding vibration the patch follows more closely, and at last is completely covered by the tail while it passes. This is called a *disappearance*. After a few vibrations it appears again, preceding the tail. This is called a *reappearance*. The time of disappearance was generally considered as the time of coincidence of vibrations, though in strictness the mean of the times of disappearance and reappearance ought to be taken, but the error produced by this mistake is seldom sensible. This is very far the most accurate way of comparing the vibrations of two pendulums. It is immaterial whether the detached pendulum vibrate in a greater or less time than the clock pendulum, but it is essential to the operation that it vibrate in a smaller arc; a condition which there is no doubt of securing in these experiments.

The English observations for ascertaining the length of the seconds' pendulum at different places have generally been made by transporting an invariable pendulum whose vibrations were observed before going and after returning at London or Greenwich. The construction was similar to that of fig. 40, supposing it deprived of the knife-edge B, the tail E, and the sliding weights F and G.

Bessel's method.

A method, proposed we believe in the last century, has lately been put in practice by M. Bessel for ascertaining the length of the seconds' pendulum at Königsberg. The pendulum consists of a heavy ball suspended by a fine wire, which is made to vibrate first with one length of wire and then with a different length. The advantage proposed in this construction was the following. It is easy to measure accurately the vertical distance between two points of suspension on which the pendulum successively vibrates, and therefore (as the ball in both experiments is depressed to the same place) the difference of length of the two pendulums is easily found. This distance too is not necessarily a fractional part of the standard, and in M. Bessel's experiments was, in fact, exactly one toise. And as the small corrections depending on the diameter of the ball, &c. are easily calculated from an approximate knowledge of the length of the pendulum, the difference between these corrections is easily found. Thus the difference of length of the simple pendulums isochronous to the pendulums observed is found with great accuracy. The times of vibration being also observed (which are proportional to the square roots of these lengths) we deduce from them the proportion of the lengths. From these two data the lengths are found. Now it was supposed that this measure could be made more accurately than those necessary to Borda's method, where the diameter of the ball must be ascertained, or than those of Kater's method, where the distance between two edges is to be measured. The sort of suspension used by M. Bessel was different from the others, consisting in unwrapping the wire from a horizontal cylinder round which the upper extremity was folded. And in the observation of coincidences, instead of placing the pendulum within a few inches of the clock pendulum, it was placed at a considerable distance, and the image of the clock pendulum formed by an interposed lens was thrown upon the detached pendulum: so that all disturbance of one pendulum by the other was effectually prevented.

Carlini's method.

In some observations by M. Carlini, the upper end of the wire was attached to a small apparatus represented in fig. 46. In the upper part of this is a wheel with a sharp edge, turning like the rowel of a spur; the edge serves as a knife-edge for suspension, and by turning the wheel the suspension is changed. The piece upon which it rests is represented in fig. 47; it is supposed to project from a wall. A microscope is placed in such a manner as to view the lower edge of the wheel directly, and likewise to view its image formed by reflection in the curved surface of fig. 47; the place where they appear to meet is very accurately the place of suspension. By means of a microscope placed at the bottom, the upper and lower surfaces of the ball were viewed even during the vibration. The vibrations were observed as by M. Bessel; a plane mirror, as well as a lens, being necessary for the formation of the image of the clock pendulum.

We shall now proceed to mention, individually, some of the principal pendulum observations.

Richer's observations.

In the Ancient *Mémoires de l'Académie*, vol. vii. is Richer's account of his observations at Cayenne; which we cite as a matter of curiosity* only, it being, we believe, the first of the kind, and that which seems to have attracted Newton's attention. The vibrations of his pendulum were very small and were sensible during 52 minutes of time; they were compared with those of an excellent clock; the observation was repeated several times every week for ten months; the result was that at Cayenne the seconds' pendulum was 1½ lines shorter than at Paris. The latter he considered to be 3 feet 8⅗ lines. This is the whole of his account.

Those of Deshayes.

In the *Mémoires* for 1701, is an abstract of the results obtained by Deshayes. At Cayenne, latitude 4° 56′, he found the length of the seconds' pendulum rather less than 3 feet 6½ lines; at Grenada, latitude 12° 6′, at Martinique, latitude 14° 44′, the same; at St. Christopher, latitude 17° 19′, and several places in St. Domingo between latitude 18° 19′ and 19° 58′, 3 feet 6¾ lines; at another point in St. Domingo, latitude 19° 48′, 3 feet 7 lines. These results (about which no further account is given) are evidently worth little.

Observations by M. de la Croyère at Archangel.

In the *Petersburgh Transactions* for 1735, are recorded the observations made at Archangel by M. de la Croyère. The pendulum was a brass ball 14½ lines in diameter supported by a thread of *pite* the top of which was held by a sort of forceps. An iron measure, copied from the standard in the Paris observatory, was used for making a pendulum of the length of the seconds' pendulum at Paris, (estimated at 3 feet 8½ lines;) this length, however, was measured to the centre of the ball, and the error thence resulting was calculated. The vibrations were compared with those of a clock. The result was that the seconds' pendulum at Archangel was longer than that at Paris by $\frac{3}{20}$ of a line. Not a word is said of the temperature of the standard; and this leaves a small uncertainty as to the correct length.

By Cam bell at J maica.

In the *Philosophical Transactions* for 1734, is an account by Bradley, of the transportation of a clock with an invariable pendulum (made by Graham) from London to Black-River in Jamaica, latitude 18°. The construction of the pendulum is not described. The observations in London, which lasted 10 days, were made by Graham, and those in Jamaica, for 26 days, by Mr. Colin Campbell. At London the clock gained $1^s.2$ daily on sidereal time; and at Black-River it lost daily $2^m\ 5^s.5$. The rates were found by transit observations. A spirit thermometer was observed; and the effect of the temperature was calculated on the rough observation that clocks of this construction did not generally alter their rate at London between summer and winter above 25^s or 30^s per day. The allowance made was $8^s.7$; and thus the difference of rate depending on the alteration of gravity was $1^m\ 58^s$. This may be considered a good determination, as the greatest uncertainty from the rough estimation of the effects of temperature could not amount to more than two or three seconds per day.

By Mai at Pari

In the *Mémoires* for 1735 is Mairan's account of his observations of the length of the seconds' pendulum at Paris. A horizontal plane, movable by screws, was placed exactly 1 toise from the lower surface of his forceps. The thread was of *pite;* it was fixed in the leaden ball (6 lines in diameter) by making a small hole and burnishing the edge upon the end of the thread. The distance between the lower surface of the ball and the horizontal plane was found by trying which of several pieces of glass would just fit under it; and measuring by a scale, with the assistance of a lens, the thickness of the glass. The diameter of the ball was measured in the same way by means of a parallel ruler. The ball was left to hang on the thread one day before the experiments were begun. At first Mairan tried to count the vibrations; but was obliged at last to resort to the method of coincidences with clock pendulum. For this purpose he was obliged to use a pendulum of little more than 3 feet in length; and the distance was now measured by placing the toise on one side, and screwing up the plane till it touched the sphere. Some observations were, however, made with pendulums of 6 and 9 feet; balls of brass, ivory, &c. were also used. The mean of twelve experiments gave for the length of the seconds' pendulum 3 feet $8\frac{17}{30}$ lines. There appears to be no correction for the weight of the air nor for temperature; the mean height of the thermometer was about 13° of Fahrenheit, which is so near the temperature commonly used in the application of the French toise, that the difference may be neglected. This appears to be an excellent determination, subject only to the error of Mairan's toise, and that common to the kind of suspension that he used. But, as an isolated experiment,

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* See also the *Recueil d'Observations faites en plusieurs voyages, &c.* The length of the seconds' pendulum at Paris had been measured by Picard for the purpose of fixing a standard; and incidental observations had been made by Feuillée at Portobello and Martinique, by Halley at St. Helena, &c. They are worth very little.

it is nearly useless in the investigation of the Figure of the Earth.

The same volume contains two determinations by Godin of the Paris pendulum, one with a machine by Graham, (which is not described,) the other with a simple pendulum whose bob was the frustra of two cones united by their bases. The latter determination agrees very nearly with Mairan's: the former gives a measure shorter by $\frac{1}{6}$th of a line. At Petit Goave in St. Domingo, latitude 18° 27′, with a brass ball an inch in diameter, suspended by a line of pite which was attached with sticking-plaster, he counted 7684 vibrations and compared them with a clock, and thus found for the length of the seconds' pendulum, 3 feet 7$\frac{1}{3}$ lines. After this he used a double frustrum of a cone with a longer thread, and measured the distance to the upper surface by a sort of sliding rule. By counting 2012 vibrations he found for the length 3 feet 7$\frac{8}{15}$ lines. Bouguer (see the same volume) found 3 feet 7$\frac{1}{3}$ lines. Lacondamine used a 12-feet pendulum; but finding some difficulty in the measure, he adopted a pendulum of little more than 3 feet, which was attached to the slider of his beam-compasses; he found 3 feet 7$\frac{11}{60}$ lines.

At Porto-bello, latitude 9° 33′, Godin and Bouguer found 3 feet 7$\frac{7}{90}$ lines for the length of the seconds' pendulum; at Panama, latitude 8° 35′, they found 3 feet 7$\frac{1}{5}$ lines; at Punta-Palmar, 2′ South latitude, Lacondamine found 3 feet 6.96 lines; at Riojama 9′ South, Bouguer found 3 feet 6.82 lines, and Lacondamine 3 feet 6.93 lines; at Quito, 25′ South, they found 3 feet 6.83 lines. The elevation of the last-mentioned place makes it almost unsafe to use such a measure in conjunction with those taken near the level of the sea. We copy these numbers from the table near the end of the IVth volume of the *Œuvres de* Maupertuis. The numbers given by Bouguer himself in his *Figure de la Terre*, for the length of the seconds' pendulum in vacuum, are: at the Equator, at an elevation of 2434 toises, 36 inches 6.69 lines; at an elevation of 1466 toises, 36 inches 6.88 lines; at the level of the sea, 36 inches 7.21 lines; at Porto-bello, 36 inches 7.30 lines; at Petit Goave, 36 inches 7.47 lines; at Paris, 36 inches 8.67 lines.

Maupertuis observed the rate of an invariable pendulum attached to a clock, at Paris and at Pello, latitude 66° 48′. This instrument was made by Graham: the pendulum was of brass, suspended by a knife-edge of steel which rested on steel planes. The temperature of the places of experiment at Paris and at Pello was the same, and the extent of the arcs of vibration the same. At Pello it gained $59^s.1$ per day on its Paris rate. At London it appeared from Graham's observations that it gained $7^s.7$ per day on its Paris rate. The observations at Pello lasted four days. As they feared that in a country full of iron and magnetic stones there might be some magnetic influence, they tried in another clock bobs of different metals, but the difference at Pello and Paris was the same in all. Great confidence may be placed in this kind of observation, where one of the principal difficulties (that of measuring the pendulum) is entirely avoided.

In 1752, (see *Mémoires* for 1751,) Lacaille observed the length of the seconds' pendulum at the Cape of Good Hope and the Isle of France, and on his return, at Paris. The length at the Cape, given in the *Mémoires*, is 3 feet 8.07 lines. In Delambre's *Histoire de l'Astronomie au XVIIIme. Siècle*, p. 478, M. Mathieu has given the results of a recalculation of all Lacaille's observations: they are as follows. Length of seconds' pendulum at the Isle of France, latitude 20° 10′ South, 3 feet 7.785 lines; at the Cape of Good Hope, 33° 55′ South, 3 feet 8.139 lines; at Paris, 48° 51′ North, 3 feet 8.79 lines. These results are comparable among themselves, but are not strictly comparable with others, because some corrections are introduced by M. Mathieu which were not introduced by observers of that age.

Observations of Pendulums.

By Legentil.

In the *Voyage dans les Mers de l'Inde* of Legentil, published 1779, are contained observations of the pendulum at Pondicherry, latitude 11° 56′ North; at Manilla, latitude 14° 34′ North; and at Foul-point in Madagascar, latitude 17° 40′ South. They have been recalculated by M. Mathieu, (*Astronomie au XVIIIme. Siècle*, p. 698.) who observing that the standard was the same as Bouguer's, and therefore that Bouguer's and Lacaille's observation at Paris might be considered as comparable with these if the same reductions were made in all, has applied to all the same reductions, and thus found the following comparable lengths: Paris, 3 feet 8.582 lines; Pondicherry, 3 feet 7.345 lines; Manilla, 3 feet 7.517 lines; Foul-point, 3 feet 7.441 lines.

By Phipps, at Spitzbergen

In the account of Phipps's voyage towards the North Pole (made 1773) are some observations with an invariable clock pendulum made by Graham. The ball was a brass sphere 4 inches in diameter; the rod a steel wire $\frac{1}{10}$th of an inch thick; it turned upon knife-edges, which were not left quite sharp, the edge being rounded to a cylinder of $\frac{1}{400}$ inch radius. These knife-edges turned in notches made in two pieces of hardened steel; the notches were angular and rounded at the bottom. The rod was not fixed firmly to the knife-edges, but attached to a pin whose direction was parallel to the plane of vibration, in order that an equal bearing on both extremities might be ensured. The escapement was not absolutely a dead-beat, but slightly recoiling; as it is well known to artists that a pendulum on a knife-edge suspension may be thus made to vibrate in equal times under the action of very different weights. At London the clock went exactly mean solar time. On a small rocky island* near Spitzbergen, latitude 79° 50′ North, an equatorial was mounted as an altitude and azimuth instrument, and at about five in the afternoon the transit of the Sun's limb over the vertical wire was observed: this observation was repeated the next day. Besides this, the clock was compared with a chronometer, whose rate was well known. A correction was applied for the temperature. The conclusion was that the rate was accelerated $72^s.28$ per day. Again, in latitude 79° 44′ North, the clock was kept going for about three days, and compared with the chronometer, whose rate was determined by many altitudes of the Sun immediately before and after the observations. The acceleration, thus determined, was $73^s.06$ per day. On returning from the voyage, the clock was found to go true time at London. These results appear to be perfectly trustworthy.

By Borda, at Paris.

We have already described at great length the manner in which Borda's observations were made at Paris. We shall merely add that the pendulum was about 12 feet long, so that every vibration corresponded nearly to every second vibration of a clock. The whole apparatus was enclosed in a box, to prevent currents of air

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* This is very near to the place where Captain Sabine afterwards observed the pendulum, but it does not appear to be the identical spot.

from affecting it. All the corrections which we have mentioned were applied, except that for elevation above the sea. The mean result from twenty experiments of four or five hours each, was 3 feet 8.5593 lines. See the *Base du Système Métrique*, tom. iii.

By Biot, on the French meridian.

The same methods were followed (see tom. iv. of the same Work) by Biot (except that he used a pendulum of about 3 feet in length) at Formentera, latitude 38° 40′; at Paris, latitude 48° 50′; at Bordeaux, latitude 44° 50′; at Figeac, latitude 44° 37′; at Clermont, latitude 45° 47′; at Dunkirk, latitude 51° 2′; at Leith Fort, latitude 55° 59′; and at Unst, in the Shetland Islands, latitude 60° 45′. The lengths were reduced to those which would have been observed at the level of the sea by increasing them in the duplicate ratio of the actual distance from the Earth's centre to the distance of the level of the sea from the Earth's centre; this amounts to the same as neglecting the attraction of the elevation on which they were placed. The results are respectively, (in mètres,) 0.7412520, 0.7419175, 0.74160863, 0.741612279, 0.7417052, 0.7420761, 0.994531014, and 0.742723136. All of these, it must be observed, are lengths of the decimal pendulum (making 100,000 oscillations in a mean solar day) except the last but one, which is the length of the sexagesimal seconds' pendulum. All these determinations must be considered as most valuable. Two invariable pendulums also were observed at Greenwich and at Paris; they appeared to show a retardation at Paris of 10^s.79 daily; but it is expressly remarked, that the circumstances were very unfavourable to accuracy.

By Malaspina.

In the Additions to the *Connaissance des Temps* for 1816, is M. Mathieu's account of the observations made in an expedition under the command of Malaspina, undertaken by order of the Spanish Government, from 1789 to 1794. Their pendulum had a wooden rod; it was enclosed in a glass box; the vibrations were counted by two persons, who relieved each other at the end of every sixty; a third person stood at the clock. The following are their results for the length of the seconds' pendulum (taking for unit the length of the simple pendulum equivalent to their pendulum.)

Place.	Latitude.				Length.
Mulgrave........	59	34	20	N.	1.0082893
Nutka	49	35	15		68172
Montercy........	36	35	45		54463
Cadiz...........	36	31	46		57192
Macao	22	12			42378
Acapulco........	16	50	49		43770
Manilla.........	14	35	49		45051
Umatag..........	13	17	52	N.	39539
Zamboanga	6	54	27	S.	40541
Lima.	12	4	38		41320
Isle Babao.......	18	35	45		45384
Port Jackson	33	51	20		56969
Monte Video	34	54	38		57973
Conception	36	42	32		57471
Port St. Helena ..	44	29	34		69083
Port Egmont.....	51	21	3	S.	71070

These results cannot be compared with any others, as scarcely any other observation (except Legentil's) has been made at any of these places for the determination of the absolute length of the pendulum.

In the *Phil. Trans.* for 1818, are contained Captain Kater's observations for determining the length of the seconds' pendulum at Portland Place, London. The principle we have already described: the result was corrected for extent of vibration by observing the arc at each coincidence and using the mean between two adjacent arcs for the vibrations between them; for temperature, by allowing 0.423 vibration for each degree of Fahrenheit; and for the weight of the air and elevation above the sea in the manner that we have described. They gave for the length in latitude 51° 31′ 8″, 39.13860 inches. But in the *Phil. Trans.* for 1819, Dr. Young remarked that the correction usually applied for the elevation above the sea was too great, as it neglected the attraction of the elevated mass. If we stood on a sphere of the same density as the Earth's mean density, the reduction would be but ¾ of that which is usually made; on a hemisphere, still less; on table land of mean density, the reduction would be ¼ of that usually made; on table land of density = ⅔ mean density, it would be ½; on table land whose density $= \frac{2.5}{5.5} \times$ mean density (which would probably represent pretty nearly the density of most rocks at the Earth's surface) the reduction would be $1 - \frac{3}{4} \quad \frac{2.5}{5.5}$, or $\frac{66}{100} \times$ usual reduction. The last result thus reduced, and with other corrections, is 39.13929 inches. This is the number used in all the subsequent comparisons.

Obse tions Pendu By K Londo

Dr. Y corre for el tion.

The same Volume (for 1819) contains Captain Kater's determinations (by the transportation of an invariable pendulum) at Shanklin in the Isle of Wight, latitude 50° 37′; at Arbury Hill, latitude 52° 13′; at Clifton, latitude 53° 28′; at Leith Fort, latitude 55° 58′; at Portsoy, latitude 57° 41′; and at Unst, latitude 60° 45′. The results were 39.13614, 39.14250, 39.14600, 39.15554, (obtained under unfavourable circumstances,) 39.16159, and 39.17146 inches.

Obse tions Kate Engl meri

In the history of Captain Ross's voyage to Baffin's Bay (made in 1818) is an account of the going of a clock (with invariable pendulum vibrating on a knife-edge, which rested on hollow cylinders of agate) as determined by 7 days' observation at London, 3 days at Brassa in the Shetland Islands, latitude 60° 1′, and 4 days at Hare Island, latitude 70° 26′. And in Parry's first voyage are observations on the going of two similar clocks at London, before and after the voyage, and at Melville Island, latitude 74° 47′, during 38 days. The result* (see *Phil. Trans.* 1821) is, that at Brassa the length of the seconds' pendulum is 39.16929; at Hare Island 39.1984; and at Melville Island, 39.2070 inches.

Obse tion Ross Par voy

In the *Phil. Trans.* for 1823, are detailed accounts of observations made by Captain Basil Hall and Mr. Foster with an invariable detached pendulum at London; at Abingdon Island, one of the Galapagos, latitude 0° 32′; at San Blas de California, latitude 21° 30′; and at Rio de Janeiro, latitude 22° 55′ South. In this, as in

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* In the *Connaissance des Temps*, 1827, *Additions*, M. Arago has given his opinion that these observations would be rejected without scruple if they opposed any received theory, and that, therefore, they are useless when they favour it. With the greatest possible respect for the opinion of this illustrious philosopher, we must in this instance withhold our assent to it. The conclusion is not so accurate as if deduced from the use of invariable detached pendulums, but it is probably much superior to that which would be obtained in difficult circumstances by the French method. From our own experimental acquaintance with these clocks, we know them to be excellent.

other instances, we cannot enter into the details, and can only state that the operations appear quite satisfactory. The resulting lengths of the seconds' pendulum are 39.01717, 39.03829, (by a mean;) and 39.04375.

In the same Volume is an account of observations made by Sir Thomas Brisbane, Mr. Rumker, and Mr. Dunlop, with an invariable detached pendulum at London and Paramatta in New South Wales, latitude 33° 49′ South. The length of the seconds' pendulum at the latter is 39.07696.

Captain Sabine's *Account of Experiments to determine the Figure of the Earth*, &c. published in 1825, contains a very valuable* series of observations made with two detached invariable pendulums. The principal novelties in the manner of conducting the observations was, that for coincidences the mean of disappearances and reappearances was taken; and that the correction for temperature was determined from experiments made at London in different temperatures; the effect of an alteration equal to 1° of Fahrenheit was found to be 0.421 vibrations per day. Two clocks with invariable attached pendulums (the same which were used on Captain Parry's voyage) were also observed. The results, as finally corrected in the *Phil. Trans.* for 1828, will be given in our general table.

In 1809 experiments† were made at Madras observatory by Captain Warren, with a leaden ball 1⅛ inch diameter, suspended by a fibre formed from the wild plantain tree. Its vibrations were counted, and the time of an astronomical clock noted by an assistant. For the measure, plates of glass were fixed to the wall, and paper attached to them, and upon these a scale was transferred from Colonel Lambton's scale. The beam compasses were applied to the lower surface of the support, and the lower surface of the ball, and were then taken to the scale. The diameter of the ball was inferred from its weight. From 10 days' observations the length of the seconds' pendulum was found to be 39.026273 inches (in air, and measured by Lambton's scale.) This determination is certainly inferior to one that we shall presently give.

In 1821 an expedition under the direction of Mr. Goldingham, made observations at Pulo Gaunsah Lout (a small island in latitude 1′ 49″ North) with an invariable pendulum, which had been observed at London. The deduced length of the seconds' pendulum is 39.021260 inches. Every care appears to have been taken to make this accurate.

The *Phil. Trans.* for 1822 contain Mr. Goldingham's determination, with the same pendulum, of the length of the seconds' pendulum at Madras, latitude 13° 4′: it is found to be 39.026302, and appears to be very accurately determined. In this, and in the last, the reduction for temperature is applied in a very confusing manner; but we have satisfied ourselves that it is correct.

In the *Phil. Trans.* for 1826 is Lieutenant Foster's account of a very careful series of observations at Port Bowen, latitude 73° 14′, with an invariable pendulum which had been observed at Greenwich. The conclusion was that the length of the seconds' pendulum = 39.203472 inches. This, however, is founded on the supposition that 39.13911 is the length of the seconds' pendulum at Greenwich, reduced to the level of the sea. It is, however, nearly the length at Portland Place, London. We shall soon mention the difference between these lengths.

By Freycinet in various latitudes

The French expedition sent out in 1817—1820, under Captain Freycinet, made observations at Paris; at Rio de Janeiro, latitude 22° 55′ South; at the Cape of Good Hope, latitude 33° 55′ South; at the Isle of France, latitude 20° 10′ South; at Rawak, near New Guinea, latitude 0° 2′ South; at Guam, the capital of the Marian Islands, latitude 13° 28′; at Mowi, one of the Sandwich Islands, latitude 20° 52′; at Port Jackson, latitude 33° 52′ South; and in the Isles Malouines, latitude 51° 35′ South. Three invariable brass pendulums were used, and one wooden one. When observed, they were enclosed in glass boxes, and a small clock placed near them had its pendulum adjusted, till it vibrated exactly in the same time. This clock (used only as a counter) was compared with a chronometer every half hour; for determining the rate, the mean of five chronometers was used. The proportionate lengths of the seconds' pendulum are 1.00002271, 0.99783528, 0.99871582, 0.99794[illegible], 0.99709575, 0.99759331, 0.99792816, 0.99877424, 1.00022319. These determinations are probably pretty good. See the *Voyage autour du Monde, &c. par* Freycinet.

By Duperrey in the Pacific.

In a similar expedition made in 1822—1825 under Captain Duperrey, two of the same pendulums were employed. The method appears to have been the same as in the operations last described. The following are given as representing the lengths of the seconds' pendulum. At Paris, 1; at Toulon, latitude 43° 7′, 0.99950585; at the Malouines, 1.00025995; at Port Jackson, 0.99871430; at the Isle of France 0.99789022; at Ascension, latitude 7° 56′ South, 0.99729881. We extract these numbers from the *Additions* to the *Conn. des Temps*, 1830.

By Sabine at Paris.

The *Phil. Trans.* for 1828 contain Captain Sabine's observations on an invariable pendulum at London and at Paris. From an extensive series it appears that a pendulum which at London makes 85,940 vibrations per day, is retarded at Paris to the amount of 12.03 vibrations. As the length of the seconds' pendulum at London, uncorrected for elevation, is 39.13908 inches, the length at Paris is 39.12813. This is a very valuable determination, as it makes a great number of determinations comparable, which without it could not safely be brought together.

By Sabine at Greenwich.

In the *Phil. Trans.* for 1829 is a series of observations by the same gentleman for determining the difference of gravity at Portland Place, London, and the Royal Observatory, Greenwich. It appears that at Greenwich, no correction being applied for elevation, the pendulum is accelerated about 0.48 of a vibration per day, and therefore, the length of the seconds' pendulum at Greenwich is greater than at Portland Place by .000435. If the correction for elevation be applied, according to Dr. Young's rule, the difference is 0.60 of a vibration, or .000544 inch in the length. We do not ourselves believe that the pendulum, as commonly constructed, can be relied on to this degree of accuracy.

The same Volume contains experiments leading to a very remarkable result with regard to the correction for the weight of the air. They are, in fact, a repetition of

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* The publicity of some discussions respecting these observations compels us to give our own opinion. We shall decline entering into any inquiry respecting the original observations, and shall merely state that we have the most perfect confidence in the results.

† The accounts of this and the next set of experiments were presented by the East India Company to the Astronomical Society of London, by favour of whom we have been allowed to inspect them.

experiments announced by Bessel in the *Astronomische Nachrichten*, No. 128, and published in the *Berlin Transactions* for 1826. It would seem that a quantity of air moves with the pendulum, and adds to its inertia, and therefore that besides a retardation arising from the diminished weight of the pendulum, there is another retardation arising from the increased mass of matter to be put in motion. A pendulum was made to vibrate in air, in vacuum, and in hydrogen gas, of elasticity equal to the elasticity of the atmosphere. It appears that the reduction to vacuum, as commonly made, ought to be increased in the ratio of 1 : 1.655. With a spherical bob, the reduction ought to be doubled. As, however, all the comparative observations have been made with little difference in the height of the barometer, the error in the reduction has very little effect on their results. It is remarkable that the correction for hydrogen gas appears to be double of what it would be if we supposed the amended corrections proportional to the Specific Gravities of the fluids. Bessel determined the atmospheric correction by observing the length of the seconds' pendulum in air, first with a bob of brass, and secondly, with a bob of ivory. The correction, being greater for the latter than for the former, in the proportion of the Specific Gravities, was determined with great accuracy from the difference of the observed lengths.

Experiments by Bessel and Sabine to determine the effect of the air on the vibrations of a pendulum.

Observations by Biot in the Mediterranean and Italy.

The *Mémoires de l'Institut*, vol. viii. contain a paper by M. Biot, from which we extract the following determinations by himself of the length of the seconds' pendulum at Milan, latitude 45° 28′; at Padua, latitude 45° 24′; at Fiume, latitude 45° 19′; at Barcelona, latitude 41° 23′; at Formentera, latitude 38° 40′; and at Lipari, latitude 38° 29′. Expressed in millimètres they are 993.547642. 993.607294, 993.584075, 993.2321312, 993.0696597, 993.0791638. The former determination at Formentera, it appears, was not satisfactory. The details of these experiments are not given.

By Rumker in New South Wales.

The IIId Volume of the *Transactions of the Astronomical Society* contains a series of observations in Borda's method, made by Mr. Rumker at Paramatta. It appears that the length of the pendulum was measured by screwing up the steel plate, first till it touched the ball, then till it touched the measuring bar. The diameter of the ball was measured by winding a thread eleven times round it. The result in millimètres is 992.412801. Many details of the calculation are omitted.

By Fallows at the Cape of Good Hope.

In the *Phil. Trans.* for 1830 is a determination by Mr. Fallows, of the proportion of Gravity at London and at the Cape of Good Hope with an invariable pendulum. The number of vibrations per day at London was 86164.97, and at the Cape 86097.86. With the length 39.13929 inches for the seconds' pendulum at London, we find for the Cape 39.07836.

By transportation of an invariable pendulum, (from London, we believe,) Svanberg ascertained the length of the seconds' pendulum at Stockholm, latitude 59° 21′, to be 39.165414 inches. We are unable to refer to the original account of this experiment.

The length of the pendulum at Königsberg, latitude 54° 42′, reduced to the level of the sea, has been found by Bessel (by his method described above) to be 440.8179 lines. The two pendulums whose difference he measured, vibrated in 1″.7127 and 1″.0020. Observations of invariable pendulums transported from Paris gave a greater length. See the *Berlin Transactions* for 1826, or the *Quarterly Journal*, March, 1829.

The difference of Gravity at London and Altona has, we believe, been ascertained by Captain Sabine with an invariable pendulum. The results, so far as we know, have not yet been published.

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Observations have been made in London by Mr. F. Baily with a pendulum with two knife-edges. The pendulum consists of a massy brass bar without any bob. This construction appears to be attended with the following source of inaccuracy; if the suspension planes are not very well levelled, the pendulum will not vibrate in a vertical plane, and the time of vibration will be too great. In Captain Kater's construction this was provided against by making the bar so thin that it would bend into the proper position. Mr. Baily's results differ sensibly from those of Captain Kater.* See the *Philosophical Magazine*, February, 1829.

Section 8.—Deduction of the Figure of the Earth from Pendulum Observations.

Length
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The first element which it is important to settle is, the length of the pendulum at Paris. In these reductions we shall suppose the French foot = 1.065766 × English foot; and the mètre = 39.37079 English inches.

	Eng. Inches.
Now Borda's experiments give 440.5593 lines =	39.12776
Biot's (uncorrected for elevation) give for the decimal pendulum $0^m.7419012$, or for the sexagesimal	39.12848
Sabine's	39.12813

The mean is 39.12812, and this is probably very accurate. If corrected for elevation by Dr. Young's rule it gives at the level of the sea 39.12877.

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From this length, and the length at London, (39.12908, or corrected by Dr. Young's rule for elevation 39.12929,) we have deduced the length at all the places where an invariable pendulum was observed. The absolute lengths measured by the French in the present century we have reduced to English measures. The absolute lengths measured in the last century we have compared with the Paris length given by the same observer, and have applied the difference to *our* value of the Paris length. Legentil's are compared as we have mentioned.

The observations may now be very well divided into first-rate and second-rate. We have reduced all of the first class to the level of the sea by Dr. Young's rule, using the multiplier .6. In the second class we have not attempted any alteration, except in Warren's, which we have corrected for the error of the standard, and reduced to vacuum.

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Now in Section 2, Art. 65, it appears that theory would lead us to expect that gravity at the latitude λ, or the length of the seconds' pendulum which is proportional to it, may be represented by $E\,(1 + F \sin^2 \lambda)$. Making this assumption for each of the lengths, and arranging them in the order of latitude, we have the following Table. Where two observers are mentioned, we have taken the mean of the lengths deduced in the way that we have described.

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[*] Mr. Baily remarks that Shuckburgh's scale seems to have sustained some injury. It appears, however, that the same divisions were used for the measure of the pendulum as for the comparison with the mètre, and nearly the same as for the comparison with other English standards; and thus the error in the result of measures which are only comparative is probably insensible.

Figure of the Earth.

Equations given by this assumption.

Deduction from Pendulum Observations.

First-rate Observations.

No.	Observers.	Place.	Latitude.	Length* of Seconds' Pendulum and Equation.	
1	Sabine	Spitzbergen	79° 50′ N.	39.21469	= E × {1 + F × .9689}
2	Sabine	Melville Island	74 47	39.2070	= E × {1 + F × .9311}
3	Sabine	Greenland	74 32	39.20335	= E × {1 + F × .9289}
4	Foster	Port Bowen	73 14	39.20419	= E × {1 + F × .9168}
5	Sabine	Hammerfest	70 40	39.19475	= E × {1 + F × .8904}
6	Sabine	Drontheim	63 26	39.17456	= E × {1 + F × .8000}
7	Biot and Kater	Unst	60 45	39.17162	= E × {1 + F × .7612}
8	Svanberg	Stockholm	59 21	39.16541	= E × {1 + F × .7401}
9	Kater	Portsoy	57 41	39.16159	= E × {1 + F × .7142}
10	Biot and Kater	Leith Fort	55 59	39.15546	= E × {1 + F × .6870}
11	Bessel	Königsberg	54 42	39.15072	= E × {1 + F × .6661}
12	Kater	Clifton	53 28	39.14600	= E × {1 + F × .6456}
13	Kater	Arbury Hill	52 13	39.14250	= E × {1 + F × .6246}
14	Kater	London	51 31	39.13929	= E × {1 + F × .6127}
15	Sabine	Greenwich	51 29	39.13983	= E × {1 + F × .6122}
16	Biot	Dunkirk	51 2	39.13773	= E × {1 + F × .6045}
17	Kater	Isle of Wight	50 37	39.13614	= E × {1 + F × .5974}
18	Borda, Biot, and Sabine	Paris	48 50	39.12851	= E × {1 + F × .5667}
19	Biot	Clermont	45 47	39.11615	= E × {1 + F × .5137}
20	Biot	Milan	45 28	39.11603	= E × {1 + F × .5081}
21	Biot	Padua	45 24	39.11896	= E × {1 + F × .5070}
22	Biot	Fiume	45 19	39.11788	= E × {1 + F × .5055}
23	Biot	Bordeaux	44 50	39.11296	= E × {1 + F × .4971}
24	Biot	Figeac	44 37	39.11215	= E × {1 + F × .4933}
25	Duperrey	Toulon	43 7	39.10952	= E × {1 + F × .4672}
26	Biot	Barcelona	41 23	39.10432	= E × {1 + F × .4370}
27	Sabine	New York	40 43	39.10120	= E × {1 + F × .4255}
28	Biot, twice	Formentera	38 40	39.09510	= E × {1 + F × .3904}
29	Biot	Lipari	38 29	39.09828	= E × {1 + F × .3872}
30	Hall	California	21 30	39.03829	= E × {1 + F × .1343}
31	Freycinet	Sandwich Islands	20 52	39.04690	= E × {1 + F × .1269}
32	Sabine	Jamaica	17 56	39.03503	= E × {1 + F × .0948}
33	Freycinet	Marian Islands	13 28	39.03379	= E × {1 + F × .0542}
34	Goldingham	Madras	13 4	39.02630	= E × {1 + F × .0511}
35	Sabine	Trinidad	10 39	39.01888	= E × {1 + F × .0342}
36	Sabine	Sierra Leone	8 30	39.01997	= E × {1 + F × .0218}
37	Hall	Galapagos	0 32	39.01717	= E × {1 + F × .0001}
38	Sabine	St. Thomas	0 25	39.02074	= E × {1 + F × .0001}
39	Goldingham	Pulo Gaunsah Lout	0 2 N.	39.02126	= E × {1 + F × .0000}
40	Freycinet	Rawak	0 2 S.	39.01433	= E × {1 + F × .0000}
41	Sabine	Maranham	2 32	39.01213	= E × {1 + F × .0020}
42	Sabine and Duperrey	Ascension	7 55	39.02363	= E × {1 + F × .0190}
43	Sabine	Bahia	12 59	39.02433	= E × {1 + F × .0505}
44	Freycinet and Duperrey	Isle of France	20 10	39.04684	= E × {1 + F × .1189}
45	Hall and Freycinet	Rio de Janeiro	22 55	39.04350	= E × {1 + F × .1516}
46	Brisbane and Rumker	Paramatta	33 49	39.07452	= E × {1 + F × .3097}
47	Freycinet and Duperrey	Port Jackson	33 52	39.07919	= E × {1 + F × .3105}
48	Freycinet and Fallows	Cape of Good Hope	33 55	39.07800	= E × {1 + F × .3113}
49	Freycinet and Duperrey	Isles Malouines	51 35 S.	39.13781	= E × {1 + F × .6139}

Second-rate Observations.

50	Phipps	Spitzbergen	79° 47′ N.	39.2046	= E × {1 + F × .9686}
51	Sabine	Hare Island	70 26	39.1984	= E × {1 + F × .8878}
52	Maupertuis	Pello	66 48	39.1837	= E × {1 + F × .8448}
53	De la Croyère	Archangel	64 32	39.1414	= E × {1 + F × .6151}
54	Sabine	Brassa	60 1	39.1693	= E × {1 + F × .7502}
55	Godin and Bouguer	St. Domingo	18 27	39.0239	= E × {1 + F × .1002}
56	Campbell	Jamaica	18	39.0322	= E × {1 + F × .0955}
57	Legentil	Manilla	14 34	39.0336	= E × {1 + F × .0633}
58	Warren	Madras	13 4	39.0312	= E × {1 + F × .0511}
59	Legentil	Pondicherry	11 56	39.0183	= E × {1 + F × .0428}
60	Godin and Bouguer	Porto Bello	9 33 N.	39.0011	= E × {1 + F × .0275}
61	Legentil	Madagascar	17 40 S.	39.0267	= E × {1 + F × .0921}
62	Lacaille	Isle of France	20 10	39.0389	= E × {1 + F × .1189}
63	Lacaille	Cape of Good Hope	33 55 S.	39.0703	= E × {1 + F × .3113}

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* The whole of these (except Bessel's) are erroneous to the amount of the error in the correction for the density of the air. The magnitude of this error is nearly the same for all, and is about .0018.

Constants in the formula determined.

To determine E and F from the first-rate observations, the most favourable groups will be formed by taking for one the sum of the first 24 equations and the 49th, and for the other the sum of the 24 remaining equations. Thus we get

$$E \times \{25 + F \times 16.9070\} = 978.80528$$

$$E \times \{24 + F \times 3.8983\} = 937.16322.$$

The solution of these equations gives E = 39.01677, F[*] = .005133. These values give for the length of the Equatorial pendulum 39.01677, for the Polar pendulum 39.21704, and for the pendulum at latitude λ $39.01677 + .20027 \times \sin^2\lambda$.

Substituting these values of E and F in each of the equations, we get the following apparent errors in measurement of the pendulum, or in the number of vibrations per day.

Comparison of calculated and measured lengths.

First-rate Observations.

No	Place.	Latitude.	Observed Length.	Calculated Length.	Error in Length.	Error in Vibrations.
1	Spitzbergen ..	79° 50′ N.	39.21469	39.21081	+.00388	+ 4.3
2	Melville Island	74 47	.2070	.20324	+ 380	+ 4.2
3	Greenland ...	74 32	.20335	.20280	+ 55	+ 0.6
4	Port Bowen ..	73 14	.20419	.20038	+ 381	+ 4.2
5	Hammerfest..	70 40	.19475	.19509	− 34	− 0.4
6	Drontheim ...	63 26	.17456	.17699	− 243	− 2.7
7	Unst	60 45	.17162	.16922	+ 240	+ 2.7
8	Stockholm...	59 21	.16541	.16499	+ 42	+ 0.5
9	Portsoy......	57 41	.16159	.15981	+ 178	+ 2.0
10	Leith	55 59	.15546	.15436	+ 110	+ 1.2
11	Königsberg .	54 42	.15072	.15017	+ 55	+ 0.6
12	Clifton	53 28	.14600	.14607	− 7	− 0.1
13	Arbury Hill ..	52 13	.14250	.14186	+ 64	+ 0.7
14	London......	51 31	.13929	.13948	− 19	− 0.2
15	Greenwich ...	51 29	.13983	.13938	+ 45	+ 0.5
16	Dunkirk	51 2	.13773	.13784	− 11	− 0.1
17	Isle of Wight .	50 37	.13614	.13641	− 27	− 0.3
18	Paris	48 50	.12851	.13027	− 176	− 1.9
19	Clermont	45 47	.11615	.11965	− 350	− 3.9
20	Milan.......	45 28	.11603	.11853	− 250	− 2.8
21	Padua.......	45 24	.11896	.11831	+ 65	+ 0.7
22	Fiume	45 19	.11788	.11801	− 13	− 0.1
23	Bordeaux	44 50	.11296	.11633	− 337	− 3.7
24	Figeac	44 37	.11215	.11557	− 342	− 3.8
25	Toulon......	43 7	.10952	.11034	− 82	− 0.1
26	Barcelona ...	41 23	.10432	.10429	+ 3	0.0
27	New York...	40 43	.10120	.10199	− 79	− 0.9
28	Formentera ..	38 40	.09510	.09496	+ 14	+ 0.2
29	Lipari.......	38 29	.09828	.09432	+ 396	+ 4.4
30	California....	21 30	.03829	.04367	− 538	− 6.0
31	Sandwich Isl.	20 52	.04690	.04219	+ 471	+ 5.2
32	Jamaica	17 56	.03503	.03576	− 73	− 0.8
33	Marian Islands	13 28	.03379	.02763	+ 616	+ 6.8
34	Madras......	13 4	.02630	.02700	− 70	− 0.8
35	Trinidad	10 39	.01888	.02362	− 474	− 5.2
36	Sierra Leone.	8 30	.01997	.02114	− 117	− 1.3
37	Galapagos....	0 32	.01717	.01679	+ 38	+ 0.4
38	St. Thomas...	0 25	.02074	.01679	+ 395	+ 4.4
39	PuloGaun.Lout	0 2 N.	.02126	.01677	+ 449	+ 5.0
40	Rawak......	0 2 S.	.01433	.01677	− 244	− 2.7
41	Maranham ...	2 32	.01213	.01717	− 504	− 5.6
42	Ascension ...	7 55	.02363	.02058	+ 305	+ 3.4
43	Bahia	12 59	.02433	.02688	− 255	− 2.8
44	Isle of France.	20 10	.04684	.04058	+ 626	+ 7.0
45	Rio de Janeiro	22 55	.04350	.04713	− 363	− 4.0
46	Paramatta ...	33 49	.07452	.07880	− 428	− 4.7
47	Port Jackson .	33 52	.07919	.07896	+ 23	+ 0.3
48	C. Good Hope	33 55	.07800	.07912	− 112	− 1.2
49	Isles Malouines	51 35 S.	.13781	.13972	− 191	− 2.1

Second-rate Observations.

No	Place.	Latitude.	Observed Length.	Calculated Length.	Error in Length.	Error in Vibrations.
50	Spitzbergen ..	79° 47′ N.	31.2046	39.2108	−.0062	− 6.9
51	Hare Island ..	70 26	.1984	.1946	+ 38	+ 4.2
52	Pello	66 48	.1837	.1860	− 23	− 2.6
53	Archangel ...	64 32	.1414	.1800	− 386	−42.7
54	Brassa	60 1	.1693	.1670	+ 23	+ 2.6
55	St. Domingo .	18 27	.0239	.0372	− 133	−14.7
56	Jamaica	18	.0322	.0359	− 37	− 4.1
57	Manilla......	14 34	.0336	.0295	+ 42	+ 4.7
58	Madras......	13 4	.0312	.0270	+ 42	+ 4.7
59	Pondicherry..	11 56	.0183	.0253	− 70	− 7.8
60	Porto Bello...	9 33 N.	.0011	.0223	− 212	−23.4
61	Madagascar ..	17 40 S.	.0267	.0352	− 85	− 9.4
62	Isle of France.	20 10	.0389	.0406	− 17	− 1.9
63	C. Good Hope	33 55 S.	.0703	.0791	− 88	− 9.8

In order to compare the lengths determined from Malaspina's observations with the others, we have calculated from the formula $39.01677 + .20027 \times \sin^2\lambda$ the length at each of his stations. We have divided the sum of all these by the sum of his numbers; and have used the quotient as a common multiplier by which we have multiplied each of his numbers. The length thus produced we have called the *observed length*, and we have compared it with our *calculated length* as in the other cases.

Spanish Observations.

No	Place.	Latitude.	Observed Length.	Calculated Length.	Error in Length.	Error in Vibrations.
64	Mulgrave	59° 34′ N	39.18479	39.16565	+.01914	+21.1
65	Nutka	49 35	.12759	.13285	− 526	− 5.8
66	Montercy....	36 36	.07431	.08796	− 1365	−15.1
67	Cadiz	36 32	.08491	.08774	− 283	− 3.1
68	Macaö	22 12	.02734	.04536	− 1802	−19.9
69	Acapulco	16 51	.03275	.03360	− 85	− 0.9
70	Manilla......	14 36	.03773	.02950	+ 823	+ 9.1
71	Umatag	13 18 N.	.01631	.02737	− 1106	−12.2
72	Zamboanga ..	6 54 S.	.02020	.01966	+ 54	+ 0.6
73	Lima........	12 5	.02323	.02555	− 232	− 2.6
74	Isle Babao ...	18 36	.03903	.03714	+ 189	+ 2.1
75	Port Jackson .	33 51	.08405	.07891	+ 514	+ 5.7
76	Monte Video .	34 55	.08795	.08238	+ 557	+ 6.2
77	Conception ..	36 43	.08600	.08835	− 235	− 2.6
78	Port St. Helena	44 30	.13112	.11516	+ 1596	+17.6
79	Port Egmont .	51 21 S.	.13885	.13892	− 7	− 0.1

From an examination of these apparent errors, the following conclusions may be deduced.

1. The observations that we have called second-rate, and the Spanish observations, are perfectly useless for the investigation of the Earth's form.

2. Upon scrutinizing the errors of the first-rate observations, it would seem that, *cæteris paribus*, gravity is greater on islands than on continents. This is a conclusion, however, that cannot be adopted till the correction for elevation is ascertained with greater certainty. The stations of observation on continents, or large islands, are frequently more elevated than those on small islands; and, therefore, if our correction (the usual correction multiplied by 0.6) is too small, as it is additive, it will make the pendulum's length, reduced to the level of the sea, much too small at the continental stations and not much too small on islands. Yet we think our correction (adopted from Dr. Young) a good one, as it removes some apparent anomalies. At Clermont, for instance, an elevated station, with the usual

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[*] It is remarkable that when Newton found the decrease of gravity at the Equator to be greater than in a homogeneous spheroid, he supposed the ellipticity to be greater than for a homogeneous spheroid. We shall draw an inference exactly contrary to this.

correction, gravity appears too great; with ours there is no remarkable inequality. These considerations will show what caution must be used in adopting any theory* which rests upon very delicate differences of gravity.

3. But it is impossible to avoid remarking, that in the high North latitudes the greater number of errors have the sign +, and that about the latitude 45° they have the sign −; those about the Equator being nearly balanced. No alteration of our numbers is sufficient to correct this. If we increased the multiplier of $\sin^2\lambda$, we might make the errors at high latitudes as nearly balanced as those at the Equator: but then those about latitude 45° would be still greater than at present. To destroy these without altering the others we may add a term $- A . \sin^2\lambda . \cos^2\lambda$. We have seen in Section 2. Art. 71. that such a term ought to exist, though we could only offer a conjecture as to its magnitude. From the table of errors it would seem that the length of the seconds' pendulum would be better expressed by $39.01677 + .20277 \times \sin^2\lambda - .00880 \times \sin^2\lambda . \cos^2\lambda$. The last term is ten times as great as our imperfect theory would lead us to expect. Still, as an empirical formula, this is the best that we can offer.

4. There does not seem to be any reason for thinking that gravity is different at different longitudes; as the irregularities on different meridians do not appear greater than those at places near one another. Nor does it appear that there is any difference between the Northern and Southern hemispheres.

Now to determine the Earth's ellipticity we must refer to the formula of Section 2. Art. 65. It appears that gravity, or the length of the seconds' pendulum, being expressed by $E\,(1 + F \sin^2\lambda)$, F will $= \frac{5m}{2} - e$, and consequently $e = \frac{5m}{2} - F$; where m is the ratio of the centrifugal force at the Equator to the force of gravity there. To determine m, we have, Equatorial seconds' pendulum $= 39.01677$; hence the space through which the Equatorial gravity would make a body fall in 1^s is $\frac{\pi^2}{2} \times 39.01677$, and the velocity which it would generate in 1^s is $\pi^2 \times 39.01677$. Also (MECHANICS, § XIV.) the velocity which would be generated in 1^s by the uncounteracted centrifugal force produced by describing in T seconds a circle whose radius is R, is $\frac{4\pi^2 . R}{T^2}$; or at the Earth's Equator $\pi^2 \times \frac{4 \times 251084556}{(86164.1)^2}$.

Consequently $m = \frac{4 \times 251084556}{39.01677 \times (86164.1)^2} = .0034672$;

and $= e\,.0086679 - F$.

The question now is, what value shall we choose for F? Shall we represent the length of the seconds' pendulum by $39.01677 + .20027 \sin^2\lambda$, or by $39.01677 + .20277 \sin^2\lambda - .00880 \sin^2\lambda \cos^2\lambda$? The former gives $F = .005183$; the latter gives $F = .005197$. We are now in a case where our theory partly fails, and where it is impossible to say which of the empirical forms is more likely to be correct. If we adopt the former value of F we find $e = .003535$; if the latter, $e = .003471$. Either of these values of e is considerably greater than that which we found from the discussion of the geodetic measures (.003352).

Physical Theory of Precession and Nutation, &c.

Greater than that given by measures of arcs.

We cannot offer any conjecture as to the cause of this difference. If the regions of the Earth in middle latitudes were composed of lighter materials than the other parts, it might possibly happen that the gravity at middle latitudes (from the resulting projection of the Earth at these parts) would be diminished, while at the Poles and Equator it would be increased. The same alteration of figure would cause the ellipticity, deduced principally from measures near the Equator and in middle latitudes, to appear less than it ought. The only way of verifying such an idea would be, to measure an extensive arc of meridian near the Pole, (for we consider the Swedish arcs to be almost useless,) a thing which is not likely to be ever effected. But is such an idea worth verifying? We cannot say that it is: and we have uttered it only in the effort to produce some conjectural explanation of an apparent anomaly.

No explanation of the difference.

We can find, however, another conclusion which it is more pleasing to dwell upon. If the form of the Earth's meridian were traced on paper the nicest eye would be unable to distinguish it from a circle. The ellipticity is so small that the closest inspection without measure could not judge which was intended for the greater and which for the smaller axis. The whole quantity in dispute is less than one-sixteenth of this ellipticity. Instead of being surprised that such a difference exists, we may well be astonished at the accuracy of modern measures of all kinds which make so small a quantity a subject of controversy.

Section 9.—Physical Theory of Precession and Nutation, and Deductions of the Earth's Ellipticity from their observed Magnitudes.

Difficulty in the fundamental explanation of precession.

To point out the peculiar difficulty which at first sight appears to exist in the explanation of these phenomena, we will consider the Earth in the situation which it has at the summer solstice. In fig. 48 let S be the Sun, B the pole of the Earth whose centre is A. If now the Earth were a sphere, the attraction of the Sun upon it would not tend to disturb its motion of rotation. But from the preceding discussions it appears, that the Earth is an oblate spheroid, and that, consequently, at K and L its form is protuberant above the spherical form. The attraction of the Sun upon K is more powerful than that on the principal mass of the Earth; the attraction on L is less powerful. Considering the effect of these forces in producing motion relative to A, the effect of the former is the same as if K were drawn towards S, that of the latter the same as if L were pushed away. The effect of both of these forces seems, to twist the spheroid so as to remove B further from S. But in point of fact the effect is, to lift up the pole B from the paper, while A remains in it; B preserving the same distance from S. This is the difficulty to be explained.

Precession explained by the composition of rotatory motions.

The explanation is to be sought in the composition of rotatory motions given in the Treatise on MECHANICS, Art. 143, &c. The Earth is revolving round the axis A B. The tendency of the forces that we have described is to twist the Earth round an axis which would be represented by sticking a pin perpendicular to the paper at A. The consequence is, that at the end of a short time the Earth is revolving about an axis lying

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* Captain Sabine has observed, (we think correctly,) that in many instances the inequalities in the force of gravity appear to depend on the geological character of the stratum. On basaltic rocks, for instance, the number of vibrations is greater, and on alluvial soil less, than we should have inferred from the latitude of the station.

in the plane which passes through the pin and A B, but shifted from A B towards the pin. (We say towards the pin and not the other way, because the direction of the shifting is determined by observing on which side of the old axis the motion impressed by the extraneous forces is opposed to the motion due to the original rotation; as it is plain that the position of the new axis must be in that part where the two motions destroy each other.)

From this it appears, that the actual axis of rotation does in fact wander within certain small limits through the Earth. Since it continues to rise upwards from the paper at the extremity B while the Earth is revolving, it is easily seen that the pole describes on the Earth's surface a very small circle whose circumference = daily motion of the pole. The pole of the terrestrial ellipsoid then, whose form is determined by the rotation, will be in the centre of this small circle. And the motion will be the same as if the Earth revolved round one invariable axis, namely the axis of the ellipsoid, and this axis were lifted up from the paper.

Suppose the extraneous forces would impress in 1ˢ an angular velocity a round the axis represented by the pin; and suppose ω to be the angular velocity round the original axis. As the velocity a is not impressed at once, but by degrees, suppose the 1ˢ divided into n equal parts. At the end of the first part, the original velocity ω round A B is compounded with the velocity $\frac{a}{n}$ round the pin. The new axis (by the theorems referred to) is in a position dividing the angle between A B and the pin (a right angle) into two parts whose sines are in the proportion of ω and $\frac{a}{n}$; that is the angle which it makes with A B has for tangent $\frac{a}{n\,\omega}$. And the velocity of rotation round the new axis (see MECHANICS) is to that round the old one, as the sine of 90° to the sine of the complement of the last-mentioned angle; and consequently it $= \omega\sqrt{1 + \frac{a^2}{n^2\,\omega^2}} = \sqrt{\omega^2 + \frac{a^2}{n^2}}$. In the same manner, after the second portion of time, the angular velocity will be $\sqrt{\omega^2 + \frac{2\,a^2}{n^2}}$, &c.; and after 1ˢ or n portions of time, it will be $\sqrt{\omega^2 + \frac{n\,a^2}{n^2}} = \sqrt{\omega^2 + \frac{a^2}{n}}$. Now let the communication of the motion be gradual, that is, let n be indefinitely great, and this becomes ω. That is, the velocity of rotation is not altered. Taking up the investigation again, it will appear that in every n^{th} part of 1ˢ the axis is shifted through the angle whose tangent is $\frac{a}{n\,\omega}$: and, therefore, in 1ˢ the axis is shifted through $n \times$ angle whose tangent is $\frac{a}{n\,\omega}$, that is, making n indefinitely great, through the angle $\frac{a}{\omega}$ (as measured on the circumference of a circle whose radius = 1.)

The velocity of rotation is not altered.

Measure of the motion of the Earth's axis produced by an extraneous force.

We must begin then with calculating the value of a. Now to find the momentum of the impressed forces in producing rotation round A, we shall take the difference of the forces acting on each point P and on A (this amounts to the same as impressing on all the particles a force equal to that on A, which evidently would not alter the rotation.) The Sun's force on P $= \frac{S}{SP^2}$ (putting S for the acceleration produced by the Sun's action at distance 1): the resolved parts in the directions P N and N A are $\frac{S\,.\,PN}{SP^3}$ and $\frac{S\,.\,SN}{SP^3}$; or subtracting $\frac{S}{SA^2}$ the force on A, they are $\frac{S\,.\,PN}{SP^3}$ and $S\left(\frac{1}{SN^2} - \frac{1}{SA^2}\right)$, as S P is very nearly equal to S N. The values of these, supposing S A very great, are nearly $\frac{S}{SA^3}\,PN$ and $\frac{-2\,S}{SA^3} \times AN$. The momenta of these forces acting on a particle δm are $\frac{S}{SA^3}\,PN \times AN \times \delta m$ and $\frac{-2\,S}{SA^3}\,AN \times -PN \times \delta m$; their sum is $\frac{3\,S}{SA^3}\,AN\,.\,PN\,.\,\delta m$. Let A M parallel to the equator $= x$; M P parallel to the axis $= y$; B A S $= \theta$; then A N $= x \sin\theta - y \cos\theta$; N P $= x \cos\theta + y \sin\theta$; and the momenta of the forces is $\frac{3\,S}{SA^3} \times \{(x^2 - y^2)\sin\theta\,.\,\cos\theta + x\,y\,(\sin^2\theta - \cos^2\theta)\}\,\delta m$.

Calculation of the momentum of the Sun's attraction.

Consequently the momenta of forces upon the whole spheroid is the sum of the quantities $\frac{3\,S}{SA^3}\sin\theta\,.\,\cos\theta \int x^2\,\delta m$, $-\frac{3\,S}{SA^3}\sin\theta\,.\,\cos\theta\,.\int y^2\,\delta m$, $\frac{3\,S}{SA^3}(\sin^2\theta - \cos^2\theta)\int x\,y\,\delta m$. But since for every value of x we can find pairs of particles, whose values of y are equal, and have different signs, $\int x\,y\,\delta m$ will be 0. Also, putting a and b for the major and minor semiaxes, and ρ for the density of the spheroid, it is easily seen that $\int x^2\,\delta m$ must be proportional to $a^2 \times$ mass of spheroid, or proportional to $a^2 \times a^2\,b\,.\,\rho$, or equal to $C\,.\,a^4\,b\,.\,\rho$; and that $\int y^2\,\delta m$ must be in the same proportion to $b^2 \times a^2\,b\,.\,\rho$, or equal to $C\,a^2\,b^3\,.\,\rho$: and therefore the whole momentum of forces $= \frac{3\,S}{SA^3}\sin\theta\,.\,\cos\theta\,.\,C\,.\,a^2\,b\,(a^2 - b^2)\,\rho$. If $a = b\,(1 + e)$ where e is small, this $= \frac{6\,S}{SA^3}\,.\,\sin\theta\,.\,\cos\theta\,.\,C\,b^5\,e\,.\,\rho$.

Calculation of the momentum of inertia.

If, as in Section 2. Art. 44. we suppose the spheroid to consist of a series of spheroidal shells of different densities, the momentum of forces will be $\frac{6\,S}{S\,A^3} . \sin\theta . \cos\theta . C \int \rho . \frac{d\,(b^5\,e)}{d\,b} . d\,b$, or $\frac{6\,S}{S\,A^3} \sin\theta . \cos\theta . C . \psi\,(b)$.

Now to find a (Mechanics, § XIX.) we must divide this by the moment of inertia, or $\int (x^2 + y^2)\,\delta m$: which for a homogeneous spheroid $= C\,a^2\,b\,(a^2 + b^2)\,\rho = 2\,C . b^5 . \rho$ nearly; and for a heterogeneous spheroid $= 2\,C \int \rho . \frac{d\,(b^5)}{d\,b}\,d\,b$. Call the general integral $v\,(b)$, and the value which it has at the surface v (b), and we have for the moment of inertia $2\,C\,v\,(b)$.

Calculation of the motion of the Earth's axis produced by the Sun.

Dividing by this the moment of the forces, we have $a = \frac{3\,S}{S\,A^3} \frac{\psi\,(b)}{v\,(b)} \sin\theta . \cos\theta$: and consequently the motion of the Earth's axis in $1^s = \frac{3\,S}{S\,A^3 . \omega} . \frac{\psi\,(b)}{v\,(b)} \sin\theta . \cos\theta$; which for convenience we may call $D . \sin\theta . \cos\theta$.

Direction of this motion.

Now this motion is perpendicular to the plane passing through the Sun and the Earth's axis. In fig. 49, let B represent the place of the Pole, and ○ the place of the Sun as seen from the Earth's centre; let ♈ ♋ be the ecliptic, P the pole of the ecliptic, B b perpendicular to B ☉. Then the Earth's pole is moving with the velocity D . sin B ☉ . cos B ☉ in the direction B b. This produces an alteration in the distance of B from P, and an alteration in the place of ♋. We shall investigate these separately.

Change in the inclination of the Earth's axis to the ecliptic produced by the Sun.

First, the resolved part of the velocity of B in the direction B P is D . sin B ☉ . cos B ☉ . sin ☉ B ♋ = D cos B ☉ . sin ☉ ♋ = D cos B ♋ . cos ☉ ♋ . sin ☉ ♋. Let P B = I: then cos B ♋ = sin I. Also let the Sun be supposed to go (apparently) through the ecliptic in a year or T seconds, with a uniform motion, (the effect of the inequality of motion is not sensible,) and let t be the time since the Sun was at ♈. Then ♈ ☉ $= \frac{2\pi}{T}\,t$, and cos ☉ ♋ . sin ☉ ♋ $= \sin\frac{2\pi}{T}\,t . \cos\frac{2\pi}{T}\,t = \frac{1}{2}\sin\frac{4\pi}{T}\,t$; and the resolved velocity in the direction B P is $\frac{D}{2} \sin I . \sin\frac{4\pi}{T}\,t$. Integrating this with respect to t we find the motion in the direction B P $= -\frac{D . T}{8\pi} . \cos\frac{4\pi}{T}\,t = -\frac{D . T}{8\pi} . \cos 2$ ♈ ☉. And the inclination is changed to I $+ \frac{D . T}{8\pi} \cos 2$ ♈ ☉. It is plain that the last term is periodical: and, therefore, though the inclination is changed in the course of a year, it is the same in all successive years. The variable term is called Solar Nutation.

Precession of equinoxes produced by the Sun.

Secondly, the resolved part of the velocity of B perpendicular to B ♋ is D . sin B ☉ . cos B ☉ . cos ☉ B ♋. Now cos ☉ B ♋ = sin B ☉ ♋ . cos ☉ ♋: the expression becomes then D . × (sin B ☉ . sin B ☉ ♋) × (cos B ☉) × cos ☉ ♋ = D × (sin B ♋) × (cos B ♋ . cos ☉ ♋) × cos ☉ ♋ = D . sin I . cos I. sin² ♈ ☉ $= \frac{D}{2} \sin I . \cos I \left(1 - \cos\frac{4\pi}{T}\,t\right)$. Integrating with respect to t we have for the motion of B perpendicular to P B, $\frac{D}{2} . \sin I . \cos I . t - \frac{D . T}{8\pi} \sin I . \cos I \sin\frac{4\pi}{T}\,t$. The motion of ♋ is found by dividing this by sin I, and it is, therefore, $\frac{D}{2} . \cos I . t - \frac{D . T}{8\pi} \cos I . \sin 2$ ♈ ☉. The last term is periodic: it is considered a part of solar nutation. The first increases uniformly; it shows that ♋ is continually travelling towards ♈, or backwards: the regression in one year is $\frac{D}{2}$ cos I . T. This is called Solar Precession.

General explanatoin of lunar precession and lunar nutation.

The last investigations apply as well to the Moon as to the Sun. The only difference is that the Moon revolves in so short a time round the Earth that the periodic terms analogous to solar nutation are hardly sensible. So that putting M for the mass of the Moon, M A for her distance from the Earth's centre, $\frac{3\,M}{M\,A^3 . \omega} \times \frac{\psi\,(b)}{v\,(b)} = E$, I′ the angular distance between the pole of the earth and the pole of the Moon's orbit, T′ her periodic time; the motion of the Earth's pole during one revolution of the Moon is $\frac{E}{2} \sin I' \cos I' . T'$ in a direction perpendicular to the great circle joining the pole of the Earth, and the pole of the Moon's orbit. Now the pole of the Moon's orbit describes (nearly) a circle in 18½ years round the pole of the ecliptic. And this change of place, altering the direction and magnitude of the motion of the Earth's pole, produces the inequality called Lunar Nutation.

In fig. 50, let p be the pole of the Moon's orbit. Then the motion of the Earth's pole in 1^s will be $\frac{E}{2} \sin B\,p . \cos B\,p$ in the direction B b. The resolved part of this velocity which increases the distance of B and P is $\frac{E}{2} \times (\cos B\,p) \times (\sin B\,p . \sin P\,B\,p) = \frac{E}{2} \times (\cos B\,P . \cos P\,p + \sin B\,P . \sin P\,p . \cos P) \times (\sin P\,p . \sin P)$. Let $P\,p = I''$, and let the periodic time of p round p in a retrograde direction be T'': and let t be the

Change in the inclination of the Earth's axis to the ecliptic produced by the Moon.

time since p passed the arc P B. Then the velocity above $= \frac{E}{2} \times \left\{ \cos I . \sin I'' . \cos I'' . \sin \frac{2\pi t}{T'} + \frac{1}{2} \sin I . \sin^2 I'' \sin \frac{4\pi t}{T'} \right\}$. Integrating this with respect to t, we have for the increase of P B, $\frac{E . T'}{4\pi} \times \left\{ - \cos I . \sin I'' . \cos I'' . \cos \frac{2\pi t}{T'} - \frac{1}{4} \sin I . \sin^2 I'' . \cos \frac{4\pi t}{T''} \right\}$. These terms are one part of lunar nutation. They are evidently periodical; and, therefore, the inclination of the Earth's axis to the axis of the ecliptic is not permanently altered.

Precession of the equinoxes produced by the Moon.

Again, the resolved velocity perpendicular to P B is $\frac{E}{2} \sin Bp . \cos Bp . \cos PBp . = \frac{E}{2} \sin Bp . \cos Bp . \frac{\cos Pp - \cos BP . \cos Bp}{\sin BP . \sin Bp} = \frac{E}{2} . \cos Bp . \frac{\cos Pp - \cos BP . \cos Bp}{\sin BP} = \frac{E}{2} (\cos I . \cos I'' + \sin I . \sin I'' . \cos P) . \frac{\sin^2 I . \cos I'' - \sin I . \cos I . \sin I'' . \cos P}{\sin I} = \frac{E}{2} \{ \sin I . \cos I . \cos^2 I'' - (\cos^2 I - \sin^2 I) \sin I'' . \cos I'' . \cos P - \sin I \cos I . \sin^2 I'' . \cos^2 P \}$. Putting $\frac{2\pi t}{T'}$ for P, and integrating with respect to t, we find for the motion perpendicular to P B, $\frac{E}{2} \left\{ \sin I . \cos I . (\cos^2 I'' - \frac{1}{2} \sin^2 I'') . t - \frac{T'}{2\pi} (\cos^2 I - \sin^2 I) \sin I'' . \cos I'' . \sin \frac{2\pi t}{T'} - \frac{T''}{8\pi} . \sin I \cos I \sin^2 I'' . \sin \frac{4\pi t}{T''} \right\}$. The two last terms are evidently periodical: they are the remaining part of lunar nutation. The retrograde motion of ♋ will be found by dividing the motion of the Pole by sin I; it is, therefore, $\frac{E}{2} \left\{ \cos I . (\cos^2 I' - \frac{1}{2} \sin^2 I') t - \frac{T''}{2\pi} . \frac{\cos 2I}{\sin I} . \sin I'' . \cos I'' . \sin \frac{2\pi t}{T'} - \frac{T'}{8\pi} . \cos I . \sin^2 I'' . \sin \frac{4\pi t}{T''} \right\}$. The two last terms, which are periodical, constitute the equation of the equinoxes in longitude. The first term increases uniformly: it is called lunar precession.

Sum of solar and lunar precession.

The lunar precession in one year is found by putting T for t: it is therefore $\frac{E . T}{2} . \cos I . (\cos^2 I'' - \frac{1}{2} \sin^2 I'')$. The whole annual soli-lunar precession is, therefore, $\{ D + E (\cos^2 I'' - \frac{1}{2} \sin^2 I'') \} \frac{T}{2} \cos I$. Putting for D and E their values, this becomes $\left\{ \frac{S}{SA^3} + \frac{M}{MA^3} (\cos^2 I'' - \frac{1}{2} \sin^2 I'') \right\} . \frac{3 T \cos I}{2\omega} . \frac{\psi (b)}{v (b)}$.

To reduce this to numerical calculation, we must remark that (Mechanics, Art. 65. where u corresponds to our S, and a to our S A,) $T^2 = \frac{4\pi^2 . SA^3}{S}$, therefore $\frac{S}{SA^3} = \frac{4\pi^2}{T^2}$. Also, by the same formula, as the Moon revolves round the Earth as a centre, $\frac{\text{Earth's mass}}{MA^3} = \frac{4\pi^2}{T'^2}$: and consequently, if the Moon $= \frac{1}{n}^{th}$ of the Earth, $\frac{M}{MA^3} = \frac{4\pi^2}{nT'^2}$.* This makes the expression $\{ 1 + \frac{T^2}{nT'^2} (\cos^2 I'' - \frac{1}{2} \sin^2 I'') \} \frac{6\pi^2 \cos I}{T\omega} . \frac{\psi (b)}{v (b)}$. But since ω is the angular velocity of the Earth, T ω is evidently the angle through which the Earth revolves in a year $= 366.26 \times 2\pi$. Thus the annual precession becomes $\{ 1 + \frac{T^2}{nT'^2} (\cos^2 I'' - \frac{1}{2} \sin^2 I'') \} . \frac{3\pi . \cos I}{366.26} . \frac{\psi (b)}{v (b)}$. This is measured by an arc of a circle whose radius is 1. If we express it in seconds of a degree, it must be multiplied by $\frac{360 \times 60 \times 60}{2\pi}$: this gives for the annual precession in seconds, $\{ 1 + \frac{T^2}{nT'^2} (\cos^2 I'' - \frac{1}{2} \sin^2 I'') \} . \frac{540 \times 60 \times 60}{366.26} \cos I \frac{\psi (b)}{v (b)}$. If we knew accurately the value of n, we might compare this expression with the observed value of annual precession (which is known very accurately) and might thence infer the value of $\frac{\psi (b)}{v (b)}$. This, it is plain, would give us considerable assistance in determining the form and constitution of the Earth.

Soli-lunar precession in a form for calculation.

But as n is not very certainly known, it will be better to use also another observable quantity depending on n. The most easily observable is the first term of lunar nutation in the increase of P B. This coefficient we have found to be $\frac{E . T'}{4\pi} . \cos I . \sin I'' . \cos I''$, or $\frac{M}{MA^3} . \frac{3 T'}{4\pi . \omega} \cos I . \sin I'' . \cos I'' \frac{\psi (b)}{v (b)}$, or $\frac{3\pi T'}{nT'^2 . \omega}$

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* Instead of n we ought in strictness to have put $n + 1$. See Physical Astronomy, p. 653. The effect of this error is insensible.

$\cos I . \sin I'' . \cos I'' . \frac{\psi(b)}{v(b)} = \frac{3\pi}{n} . \frac{T''}{T} . \frac{T^2}{T'^2 . 366.26 . 2\pi} . \cos I . \sin I'' . \cos I'' . \frac{\psi(b)}{v(b)}$, which in seconds (as in the former case) $= \frac{1}{n} . \frac{T''}{T} . \frac{T^2}{T'^2} . \frac{270 \times 60 \times 60}{366.26 . \pi} . \cos I . \sin I'' . \cos I'' . \frac{\psi(b)}{v(b)}$.

Lunar nutation in a form for calculation.

Now suppose $I = 23° 28'$; $I'' = 5° 8' 38''$; $\frac{T''}{T} = 18.6$; $\frac{T}{T'} = \frac{366.26}{27.32}$; also call the whole annual precession a, and the term just mentioned b. Then on performing the calculations, we shall have these equations,

$$a = \left(4869 + \frac{864490}{n}\right) . \frac{\psi(b)}{v(b)}$$

$$b = \frac{231460}{n} . \frac{\psi(b)}{v(b)}.$$

Solving them,

$$n = 47.54 \times \frac{a}{b} - 177.56$$

$$\frac{\psi(b)}{v(b)} = .0002054 \times a - .0007671 \times b.$$

Function depending on the Earth's form deduced from observed values of precession and nutation.

The last value is the only one for which we have occasion at present.

Now a is very nearly 50.3; the value of b given by Bradley is 9.0; by Mayer 9.65; by Maskelyne 9.55; by Laplace 9.40; by Lindenau 8.99; by Brinkley 9.25. Then we get for $\frac{\psi(b)}{v(b)}$ the following values:

According to Bradley, $\frac{\psi(b)}{v(b)} = .003428$
Mayer $= .002930$
Maskelyne $= .003006$
Laplace $= .003121$
Lindenau $= .003436$
Brinkley $= .003236$.

The last value is perhaps the most probable; (it has been adopted as such by Mr. Baily in the construction of the Astronomical Society's Tables, and we think properly.) Now it must be observed that we cannot from this deduce the Earth's ellipticity without assuming some law for the density of the strata, and solving approximately a troublesome equation. For though $\psi(b) = \frac{5}{3}\left(e - \frac{m}{2}\right) b^3 . \phi(b)$, (Section 2. Art. 63.) and, therefore, $\frac{\psi(b)}{v(b)} = \frac{5}{3}\left(e - \frac{m}{2}\right) . \frac{b^3 \phi(b)}{v(b)}$, where $\phi(b)$ and $v(b)$ do not depend on e; yet the values both of e and of $\phi(b)$ and $v(b)$ will depend on the value of the constants in the law (whatever it may be;) and, therefore, when e is determined on the assumed law in terms of the constants by the formula of Section 2. and $\phi(b)$ and $v(b)$ are expressed in terms of them, there will, upon making $\frac{5}{3}\left(e - \frac{m}{2}\right)\frac{b^3 . \phi(b)}{v(b)}$ equal to one of the values above, be a complicated equation to solve. If, for instance, we assume the law mentioned in Section 2. Art. 68. and take Brinkley's value of nutation, we shall have this equation to solve

This function will not give the Earth's ellipticity without a knowledge of the law of density.

$$.003236 = \left\{\frac{5m}{2} . \frac{\frac{3f}{q^2 b^2} - 1}{\frac{q^2 b^2}{f} + f - 3} - \frac{m}{2}\right\} . \frac{f}{2 + f - \frac{6f}{q^2 b^2}},$$

Calculation with Brinkley's nutation.

where $f = 1 - \frac{qb}{\tan qb}$. Solving this by approximation, with the value $m = .0034672$, we find $q\,b = 143° 53'$; and substituting this in the expression

$$e = \frac{5m}{2} . \frac{\frac{3f}{q^2 b^2} - 1}{\frac{q^2 b^2}{f} + f - 3}, \text{ we find } e = .3323.$$

The smaller values of $\frac{\psi(b)}{v(b)}$ give smaller values for e.

We may remark that the mass of the Earth is $= \frac{4\pi}{3} \int \rho \frac{d . b^3}{db} db$ nearly, and its volume $= \frac{4\pi}{3} b^3$ nearly, therefore the mean density $= \frac{3 \int \rho . b^2 db}{b^3}$ nearly. With the law above mentioned, and the value

Figure of the Earth.

Earth's mean density compared with density at surface.

of q b just found, we find for the mean density $\frac{3\,\mathrm{A}}{q^2\,\mathrm{b}^3}$. sin q b . f, that at the surface being $\frac{\mathrm{A} \,.\, \sin q\,\mathrm{b}}{\mathrm{b}}$. The proportion of these is $\frac{3\,f}{q^2\,\mathrm{b}^2}$, or 2.20; a proportion that agrees pretty well with the results of experiments hereafter to be mentioned.

Section 10.—*Deduction of the Earth's Ellipticity from the observed Inequalities of the Moon's Motion.*

In Section 2. Art. 67. we have found for the inequality in the Moon's latitude depending on the Earth's non-sphericity, $-\left(\mathrm{e}-\frac{m}{2}\right)\times\frac{4\,.\,\overline{60}|^3}{\pi}\,\mathrm{M}\,.\left(\frac{\text{Earth's period}}{\text{Moon's period}}\right)\left(\frac{\text{Earth's radius}}{\text{Moon's distance}}\right)^2.\ \sin\mathrm{I}\,.\,\cos\mathrm{I}\,.\,\sin\theta$. This expression is, in fact, the same as Laplace's, (*Mécanique Céleste,* livre 7, No. 29.) observing that g is very nearly $= 1 + \frac{3}{4}\,m^2$ (in Laplace's notation.) If $\mathrm{I} = 23°\,28'$, and $\frac{\text{Earth's radius}}{\text{Moon's distance}} = \sin 57'$, and $\frac{\text{Earth's period}}{\text{Moon's period}} = \frac{365.25}{27.25}$, and $\mathrm{M} = \frac{70}{71}$, this is equal to $-\ 4891'' \times\left(\mathrm{e}-\frac{m}{2}\right)\times\sin\theta$. Now this inequality has been found to exist, (it has the effect of increasing the apparent inclination of the Moon's orbit in one position of her nodes, and of diminishing it as much in the opposite position,) and its magnitude has been inferred from observation. The multiplier of sin θ in Bürg's Tables is $-\ 8''.0$; in Burckhardt's it is the same. This value gives $\mathrm{e}-\frac{m}{2}=\frac{8}{4891}=.001636$; and considering m (as before) $= .003467$, we have $\mathrm{e} = .001636 + .001734 = .003370$.

Ellipticity calculated from inequality in the Moon's latitude.

From inequality in the Moon's longitude.

We have mentioned in the same place, that there is an inequality in the Moon's longitude depending on the non-sphericity of the Earth. Laplace's expression (which our limits do not allow us to investigate) is equivalent to C . sin longitude of the ascending node of the Moon's orbit, where $\mathrm{C} = \frac{19}{2}$. tan mean inclination of Moon's orbit × the coefficient of the last inequality. Making mean inclination $= 5°\,8'\,38''$, C is found $= 4183'' \times\left(\mathrm{e}-\frac{m}{2}\right)$. In Bürg's Tables C is $6''.8$; in Burckhardt's it is $7''.0$ The first gives $\mathrm{e}-\frac{m}{2} = .001626$, $\mathrm{e} = .003360$; the second gives $\mathrm{e}-\frac{m}{2}$ $.001673$, $\mathrm{e} = .003407$. Any of these values agrees nearly enough with that deduced from the geodetic measures.

Inequal of th Moon Motic

Doubts the cert of these clusion

In estimating the reliance to be placed on these values, it must be observed that they are deduced from observations which are insufficient if they do not extend over a period of nearly 20 years. The same remark applies to the deductions of the last section. This always throws a very little doubt on the accuracy of such a determination, as in all probability the observations which are compared have been made by different persons and in different manners. The small lunar inequalities, besides, are involved among a mass of terms much greater than themselves; but an error in their determination has less influence on the value of e than an equal error in the determination of nutation. We mention these things merely to show that these deductions could not be put in competition with those derived from geodetic measures, or pendulum observations, if the discordancies among the latter were not so great as to make every confirmation of their results desirable. The coincidence of the results is however satisfactory, as it gives us a strong confidence that the result deduced from the measures is not far from the truth, and that our theory is in the main correct.

Section 11.—*Observations which show that the Attraction of Masses comparatively small is sensible; and Determinations of the Earth's mean Density.*

Anom in co ing di parts same merid

Among these we may place the discrepancies which have been observed in comparing different parts of the same arc. Of these it must be confessed, that in some instances no distinct explanation can be given. At Arbury Hill, for instance, one of the stations nearly bisecting the English arc of meridian, the latitude was observed, and was found to differ about 5″ from any that could be admitted, on any supposition of the Earth's form; at Dodagoontah, on the great Indian arc, an unexplained disturbance to nearly the same amount was observed; at Takal Khera the same thing was observed; but Captain Everest appears to have accounted perfectly for this by the attraction of a range of mountains at the distance of 15 miles, (the range running Eastward from the termination of the Western Ghauts.) The magnitude of these disturbances, it must be observed, is much greater than any error that could possibly happen in the use of the astronomical instruments or in the geodetic measures, without the most unreasonable neglect. And in inferring the latitude of one place from the observed latitude of another not on the same meridian, through the medium of a geodetic measure, results have frequently been obtained which differ much from the observed latitudes. Thus (*Conn. des Temps,* 1827, *Additions*) the latitude of Turin deduced from that of Milan differs from the observed latitude by 8″.9; that of Venice by 9″.5; that of Rimini by 27″.4. We regret that in the statement which we have copied, there is no mention of the dimensions of the Earth which have been used in deducing the difference of latitudes from the geodetic measure.

In ing tud pla sm tan

In ar sa gr

Another class of observations leading to the same conclusion is the difference between the values of degrees given by different arcs passing over nearly the same ground. We have seen that in the Swedish arcs it is necessary to suppose one disturbance to the amount of 12″, or two disturbances whose sum = 12″. In the arc of parallel between Beachy Head and Dunnose, as compared with that between Dover and Falmouth, there is evidence (though less perfect) of disturbance nearly as great.

I n a

In the Piedmontese arc, if we wish to reconcile it in any degree with the arcs in greater and smaller latitudes, we must suppose that the effect of the disturbances is more than 40″. But no one who considers the situation of the alluvial basin of Piedmont, with the re of Earth.

highest part of the chain of the Alps to the North, and the Apennines (of no inconsiderable height) to the South, will doubt that this is perfectly explained by their attractions.

These observations, though they render the application of our complete theory doubtful, yet serve to give the strongest confirmation of its fundamental principle. We must not reject* them because they disagree with our theory; we must endeavour to ascertain whether they are consistent with the principle of universal gravitation, and if we find them to be consistent, we must examine what alteration must be made in the other suppositions of our theory to make it represent the facts of observation.

[illegible] for [illegible]

Now all that is necessary is, to imagine that, after the Earth had assumed a form of equilibrium and become solidified, parts of the external crust were elevated by some internal force. And if successive coatings were deposited from a fluid covering the whole, we must suppose irregularities of deposition, in many cases connected with the former, to have taken place. These inequalities, on the principle of gravitation, might account for disturbances in the Earth's form, or rather in the form of the sea, great in themselves, but small in comparison with the magnitude of the Earth. The circumstance, however, of islands being found scattered over every part of the Ocean seems to justify us in the belief that the Earth was originally fluid, and that its form has not been much altered by posterior convulsions.

The disturbances alluded to have shown the expediency, and suggested the possibility, of determining by observation the attraction of mountains; and the desire of throwing some new light on the constitution of the Earth has prompted several experiments for ascertaining the mean density of the Earth. In the last century, too, it was doubtful whether the Earth's ellipticity was less than $\frac{1}{230}$, (the value assigned by Newton,) and the determination of the Earth's mean density might (assuming the principle of gravitation) assist in settling that point. For, as has been seen, if the principal attractive mass of the Earth were at its centre, the ellipticity would be not much greater than $\frac{1}{580}$; and therefore if the central part of the Earth were more dense than the parts near the surface, the ellipticity might be expected to be less than $\frac{1}{230}$. the value which it would have if the Earth were homogeneous. The first experiment of this sort was that of Bouguer, mentioned in our first Section; of which we take no further notice, as the person who made it did not think its results worthy of any confidence.

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Determination of the Earth's mean Density.

The second was that of Dr. Maskelyne on the attraction of Schehallien. The history of this is given in our first Section; the astronomical observations are in the volume of the *Phil. Trans.* for 1775. The sector was made by Sisson, with the plumb-line passing over a dot at the centre of the instrument; it was divided by taking an arc (7° 9′ 59″.917) whose chord = ⅛th of the radius, and continually bisecting this arc: it was used with a micrometer-screw as we have described in Section 3. At each of the stations it was reversed but once. The error of collimation, as determined by a mean of the observations on the different stars, appears to have changed only a fraction of a second between making the observations on the North and on the South sides of the mountain. On the South side 76 observations were made, face East, and 93, face West; and on the North side 68 observations, face West, and 100, face East: the whole number of stars observed was 43. The situation of the observatory on each side was about half way up the hill. The difference of astronomical latitude was found to be 54″.6. The distance in feet between the parallels passing through the two observatories was found to be 4364.4 feet. This was determined by a survey of the mountain founded on two bases, one of 3012 feet and another of 5897 feet, measured with deal rods that were compared with the Royal Society's brass standard. From the extremities of these bases two cairns on the ridge of the mountain were observed, and the distance between them found. These cairns were not visible at the observatories, but signals were fixed at distant points where a cairn and an observatory appeared in the same vertical; then the angle between these signals, as seen from the observatory, was the same as that between the cairns. The same signals were observed at the cairns, instead of the observatories. The distance 4364.4 feet, at the rate of 101.64 feet to one second, (according to Bouguer's table,) gave for the difference of geodetic latitude 42″.94. The difference between this and the observed difference, or 11″.6, is to be attributed to the attraction of the mountain.

Attraction of Schehallien found by astronomical observations.

For determining the figure and dimensions of the mountain, stations were chosen all round it; then poles were fixed in the hill-side in vertical planes, as determined by observations with a theodolite in one station, and the azimuth and altitude of each was observed at another station. A few, however, were placed in horizontal planes; and some in different manners. The calculation of the attraction was made by Dr. Charles Hutton. (*Phil. Trans.* 1778.) An accurate map being made, concentric circles were described with one observatory for the centre, and with radii in arithmetical progression, their common difference being 666⅔ feet. Each of the rings between these was divided into 48 parts, according to the following law: a line being drawn in the direction of the meridian, radii were drawn making angles with it whose sines were successively $\frac{1}{12}$, $\frac{2}{12}$, $\frac{3}{12}$, &c. Then it is easily seen that the attraction (in the direction of the meridian) of each of the prisms thus formed is a constant multiplied by the sine of the angular altitude of its top. This was determined by an easy practical method, for which, with many other details, we must refer to the original Memoir. Indeed the various contrivances* of calculation in this

Survey of the mountain and calculation of its attraction.

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* In the *Phil. Trans.* 1812, is a paper by Don. J. Rodriguez, (we believe one of the gentlemen who assisted Delambre in his survey,) in which observed latitudes are compared with assumed dimensions of the Earth, and the difference is at once set down as an error of observation. The reader, who has taken the trouble to examine our Section on Meridian Measures, and its results, will judge how uncertain the dimensions of the Earth still are, and how certain it is that, using any dimensions whatever, we must still suppose some disturbing cause to affect the latitudes with errors far greater than the errors of observation. The paper in question has been severely criticised by Delambre in the *Conn. des Temps*, 1816, *Additions*. For our own part, we can scarcely imagine how any one who had been concerned with geodetic surveys, or who even knew their object, could compose such a memoir as that to which we allude.

* Most of these, it appears, were suggested by Mr. Cavendish (whose experiments we shall shortly describe.) And it appears that nearly all the preliminary calculations of the attraction of Skiddaw,

Figure of the Earth.

Paper will be found well worth the attention of any practical person. The attraction of 960 prisms was calculated at each observatory; the attraction at the North observatory was found to be to that at the South observatory nearly in the proportion of 7 : 9. And the sum of the attractions was found (supposing the density of the mountain equal to the mean density of the Earth) to be $\frac{1}{9933}$ of the Earth's attraction. But the sum of the disturbances in the direction of gravity as determined from the astronomical observations being $= 11''.6$, the sum of the attractions was, in fact, $=$ gravity $\times$ tan $11''.6 = \frac{1}{17781} \times$ gravity $= \frac{1}{17804} \times$ Earth's attraction, (allowing for centrifugal force.) Consequently the density of the mountain was to the Earth's mean density as 9933 to 17804, or nearly as 5 : 9.

Mineralogical structure of the mountain.

But this supposed that the mountain was homogeneous. The geological characters of its rocks were examined by Professor Playfair, (*Phil. Trans.* 1811,) he found that the upper part consisted of quartz whose mean Specific Gravity $= 2.6398$; and the lower part of mica slate and hornblend slate, whose mean Specific Gravity $= 2.8326$, and of limestone whose mean Specific Gravity $= 2.7661$. Two separate calculations were made; one on the supposition that the rocks were separated by vertical surfaces, and another supposing them separated by surfaces nearly horizontal. The former gave for the Earth's mean density 4.559, the latter 4.867, that of water being 1. Dr. Hutton (*Phil. Trans.* 1821) says that the number should be rather greater.

Cavendish's apparatus for observeing the attraction of leaden balls

The next experiment was that of Mr. Cavendish on the attraction of leaden balls. (*Phil. Trans.* 1798.) His apparatus is represented in fig. 51. x, x, are balls of lead about 2 inches in diameter, suspended to the ends of a light deal rod h, h. This is suspended by the wire $l\,g$, forming, in fact, a balance of torsion. The piece to which the top of the wire is attached, carries a wheel which is turned by the endless screw K F, so that the wire can be twisted till the resting-place of the balls is any required position. $n\,n$ are small graduated scales carried by the rod. The whole of this apparatus is enclosed in a mahogany box, F E A B C D D C B A E F. At A and A are small glass windows, and near these are scales serving as a vernier for measuring the motion of the scales n. These are illuminated by lamps L and L, and viewed by telescopes T and T from the outside of the room. The leaden balls W, W (each weighing 2,439,000 grains) are suspended by copper rods attached to the piece $r\,r$ which is suspended to a beam. By means of a rope passing round the pulley M M, the balls W, W can be moved without entering the room. The support of the balance of torsion and its cases is independent of the walls.

The first wire by which the deal rod was supported was of copper silvered, of which one foot weighed 2.4 grains. After a few experiments with this, it was found that the attraction of the large balls made the rod touch the sides of the case; and a stiffer wire was then used.

Determi tion of t Earth' mean Densit

Disturba produce by curre of air.

It was found at first, that a very small difference of temperature between the balls and the air produced currents of air within the mahogany case which materially disturbed the experiment. The cautions subsequently used seem to have prevented any bad effect from this cause.

Method observat

The method of observing was the following. The large balls being in the *midway position* (their supporting rod at right angles to the deal rod) the position of the deal rod was read off from the scales n. The large balls were then brought so as nearly to touch the case, sometimes in the *positive position* (in which their attraction made the rod move so as to increase the number on the scales) and sometimes in the *negative position*. By their attraction on the small balls, the rod was immediately put in motion, and vibrated backwards and forwards. The greatest extent of vibration was observed; the mean of two consecutive extreme points on one side was taken, and the intermediate extreme point on the other side; and the point midway between these was considered to be the point at which the rod would rest under the action of the balls and the torsion of the wire. The time of passing the middle point was also ascertained, by observing the time of passing two points near the middle, and then (when the middle point was determined) calculating the time of passing it. This being done for vibrations separated by a considerable number, the time of vibration was accurately found. With the wire finally used, the change from the position of rest without the action of the lead balls to the middle position when they were applied, seldom exceeded 3 divisions, (each division $\frac{1}{20}$th of an inch,) and the time of vibration was about 7 minutes. With the first wire the change was about 14 divisions, and the time nearly 15 minutes.

Metho calcul

The middle point is evidently the place where the attraction of the large balls is equal to the force of torsion of the wire. The time of vibration also depends on both of these forces. For suppose that at the middle point the distance of the small balls from the large ones was A, and the space through which they had been moved (to which the force of torsion is proportional) B; then putting W and T to represent these forces respectively at the distance 1, we shall have this equation $\frac{W}{A^2} = TB$. And at the distance x beyond this, and further from the balls, the whole force tending to bring the balls to the middle point is $T\,(B + x) - \frac{W}{(A - x)^2} = TB - \frac{W}{A^2} + \left(T - \frac{2\,W}{A^3}\right) x$ nearly, $= \left(T - \frac{2\,W}{A^3}\right) x$; and this is the force on which the time of vibration depends. Thus there are, in fact, two equations to be solved, from which the attraction of the balls and the torsion of the wire could be determined. Besides this, the attraction of the mahogany case was calculated. The attraction of the leaden balls being thus determined, and compared with the attraction of the Earth, the proportion between the Earth's mean density and the density of lead was found; and thus the Earth's mean density is obtained. The result of 29 experiments (as corrected by Dr. Hutton, *Phil. Trans.* 1821) is 5.31, that of water being 1. The smallest number given by one experiment is 4.86, and the largest 5.79.

We are upon the whole inclined to prefer this result to that of the observations on Schehallien. It cannot

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&c. were made by Mr. Cavendish. This we have ascertained from an inspection of his papers, which we have had an opportunity of examining through the kind permission of his Grace the Duke of Devonshire.

Result probably preferable to the former.

be denied that the greatest delicacy was necessary to obtain any result, and that the determination is much less certain than the determination (such as it is) by the Schehallien experiment. But we consider that the quantity determined in the latter may be something very different from the attraction of the mountain. We have seen that at Arbury Hill, and some other places, there is evidence of disturbance to an amount nearly as great as the attraction of Schehallien, and without any known cause. May not such unknown causes have operated as well in the Schehallien experiment, and have increased or diminished the apparent effect of the mountain?

Considering the Earth's mean density as somewhat greater than 5, and the mean density of the rocks at the surface as 2.6, the proportion of the Earth's mean density to the superficial density is not very different from that of 2 : 1.

We have mentioned in our first Section the attempt made by the Baron de Zach to measure the attraction of a mountain near Marseilles. We have only to add that no calculation of the Earth's density was founded on these observations.

The attraction of a mountain might be found by observing the length of the seconds' pendulum on the top; if gravity should thus be found to be greater than gravity at the level of the sea in the same latitude diminished in the duplicate proportion of the distance from the Earth's centre, the excess would be attributable to the attraction of the mountain. Bouguer (as we have mentioned in Section 7.) observed the pendulum on one of the peaks of the Andes; but the circumstances were unfavourable, and we should have no confidence in the results. In the present century (see the *Additions* to the *Milan Ephemeris*) M. Carlini made similar observations in much more favourable circumstances at the hospice of Mont Cenis, at an elevation of 6375 feet above the level of the sea. The pendulum we have described at the beginning of Section 7: twenty experiments were made with it; they were reduced like the French measures, and corrected for elevation by the rule of inverse squares; the length at the level of the sea thus found was in mètres 0,993708. But the observations of Biot at Bordeaux, nearly at the level of the sea, corrected for the small difference of latitude, gave 0.993498. The difference is due to the attraction of the mountain mass. Representing this by a segment of a sphere, 1 geographic mile in height and 11 in diameter at the base, of Specific Gravity 2.66, the mean density of the Earth is calculated to be 4.39. Perhaps this experiment would have been more satisfactory if the pendulum had been made exactly like the French pendulums, or if an invariable pendulum had been used. As it stands, there is one considerable source of error,* namely, the erroneous reduction fōr the effect of the air (mentioned in Section 7.) The barometer at Mont Cenis being several inches lower than at Bordeaux, this error would be serious. Besides, we could hardly trust to a comparison between two places at so great a distance. On the whole, we do not think that any estimation of the Earth's density can be founded on this experiment.

The result erroneous and doubtful if corrected.

Section 12.—*Conclusion.*

Conclusion.

1. The measures of the Earth, the observations of pendulums, and the lunar inequalities, agree in showing that the Earth's form does not differ much from that of an ellipsoid of revolution whose ellipticity is (we think certainly) greater than $\frac{1}{300}$, and whose major semiaxis is about 20,923,700 English feet.

2. The phenomena of precession and nutation give an ellipticity rather smaller; but as no result can be deduced from them except on an assumed law of density, this value cannot be put in opposition to the others.

3. As the results of the pendulum observations, the lunar inequalities, and the precessional phenomena, can only be used to determine the Earth's form by the intermediation of the principle of gravitation, the very near coincidence of the results is a strong argument in favour of the truth of that principle.

4. The same things make it highly probable that the Earth has once been in a fluid or semi-fluid state.

5. None of these results can be obtained without the admission of considerable anomalies, all of which, however, appear to be consistent with the principle of gravitation.

6. The mean density of the Earth considerably exceeds, and is probably double of the density of the superficial rocks.

7. The near agreement of the proportion between these as deduced from an assumed law with the proportion found by the experiments with leaden balls (where it is assumed in the calculation that the law of gravitation holds good at the distance of a few inches) makes it probable that the law is sensibly true to very small distances.

G. B. AIRY.

Observatory, Cambridge,
August 17, 1830.

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* If we correct this, by doubling the usual reduction, (the pendulum-balls being spherical,) the length at Bordeaux is 0.993553, and that at Mont Cenis, reduced for elevation, 0.993754; whence the mean density of the Earth = 4.59.

POSTSCRIPT.

Figure of the Earth.

The author has discovered a small error in the Table of the observed lengths of the seconds' pendulum. The reduction applied to the length of the Paris pendulum for elevation above the sea is that due to the *decimal* pendulum. In consequence, the length at Paris, and all the lengths depending on it, ought to be increased by .00013; a quantity which does not sensibly affect any of the results. This correction applies to Nos. 18, 25, 31, 33, 40, 44, 47, 49; and half of it to Nos. 42, 45, 48.

The multiplier 0.6 has been used (in reducing the foreign observations) in preference to 0.66, as it seems probable that the density at the Earth's surface is greater, and the mean density less, than Dr. Young supposed. The multiplier 0.66 is adopted for the English observations from the calculations of the respective observers; the effects of this inconsistency are not sensible.

Postscr

In the determination of the length of the seconds' pendulum at Königsberg, a correction is included which is not applied to any of the other observations. The reason is that the effect of this correction is to increase the length of the seconds' pendulum; and it appears that the observations on which Bessel principally relied, give a smaller length than those made in the usual way. The difference depends probably on the difference of the apparatus employed.

TIDES AND WAVES.

INTRODUCTION.

WE propose, in this article, to enter at some length into the mathematical theories, and the experimental observations, applying to the two subjects of Tides and Waves of water. But we do not intend to treat them with the same extension. We shall give the various theories of Tides in detail sufficient to enable the reader to understand the present state of the science which regards them; and we shall advert to the principal observations which throw light either on the ordinary phænomena of tides, or on the extraordinary deviations that occur in peculiar circumstances. In thus treating the Tides, it will be necessary for us to enter largely into the theory of Waves. We shall take advantage of this circumstance for the introduction of several propositions, not applying to the theory of Tides, but elucidating some of the ordinary observations upon small Waves. But these investigations will be limited to that class which is most closely connected with tides, namely, that in which similar waves follow each other in a continuous series, or in which the same mathematical process may be used as when similar waves follow each other. In this class will be included nearly all the phænomena of waves produced by natural causes, and therefore possessing general interest. But it will not include the waves of discontinuous nature produced by the sudden action of arbitrary causes, which have been the subject of several remarkable mathematical memoirs, but which possess no interest for the general reader.

The general plan of this Essay will be as follows:—

I. We shall describe cursorily the ordinary phænomena of Tides.

II. We shall explain the *Equilibrium-Theory of Tides*, including the first tidal theory given by Newton, and the more detailed theory of his successors, especially Daniel Bernoulli.

III. We shall give a sketch of Laplace's investigations, (founded essentially on the theory of the *motion* of water,) in the general form in which he first attempted the theory, as well as with the arbitrary limitations which he found it necessary to use for practical application.

IV. We shall give an extended Theory of Waves on water, applying principally to the motion of water in canals of small breadth, but with some indications of the process to be followed for the investigation of the motion of Waves in extended surfaces of water.

V. The results of a few Experiments on Waves will be given, in comparison with the preceding theory.

VI. We shall investigate the mathematical expressions for the Disturbing Forces of the Sun and Moon which produce the Tides, and shall use them in combination with the theory of Waves to predict some of the laws of Tides.

VII. We shall advert to the methods which have been used, or which may advantageously be used, for Observation of Tides, and for the Reduction of the Observations.

VIII. We shall give the results of extensive observations of the Tides, as well with regard to the change of the phænomena of tides at different times in the same place, as with respect to the relation which the time and height of tide at one place bear to the time and height at other places, and shall compare these with the results of the preceding theories, as far as possible.

And as Conclusion, we shall point out what we consider to be the present Desiderata in the Theory and Observations of Tides.

SECTION I.—ORDINARY PHÆNOMENA OF TIDES.

Phænomena of River Tides.

(1.) If we suppose an observer stationed on the bank of a river,* at no great distance from the sea, (for instance, on the bank of the Thames any where below London Bridge, on the Humber below the mouth of the Trent, or on the Severn below the Passages,) he will remark the following changes in the state of the water.

Semidiurnal Tide.

(2.) The first and most important change is, that the surface of the water rises and falls regularly twice in every day. A short series of observations will show however that this statement is not quite correct; the tides of each succeeding day are somewhat later than those of the preceding day: the average retardation from day to day being about 40 minutes. In a short time he will find that the times of occurrence of high water bear a very close relation to the time of the Moon's appearance in certain positions; and that the language of the persons who are most accustomed to observe the tides conveys at once this relation. Thus, at Ipswich, high water occurs when the moon is south nearly: at London Bridge high water occurs when the moon is nearly south-west: at Bristol, it takes place when the moon is E.S.E. These are rude statements, but they are sufficiently accurate for many purposes; and they show at once the close connection between the time of high water and the time of the moon's passage over the meridian. In fact, so completely is this recognized, that, in order to give the time of high water upon any day, it is usually thought sufficient to

Its time is related to the apparent position of the moon.

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* We commence with this case, because, judging from the notions of sea-faring persons upon many points connected with the Tides, which are correct as regards rivers, but incorrect as regards the sea, (some of which will hereafter be indicated,) it is the case from which ideas of tidal movements have usually been taken with the greatest facility.

state the time of high water on the days of new moon and full moon, when the moon passes the meridian at twelve o'clock nearly. This time is called the *Establishment* of the port. Then to find (roughly) the time of high water on any other day, it is only necessary to add the Establishment to the time of the moon's passage.

The rules, as we have mentioned them, indicate the time of only *one* high water in the day: but the reader must understand that there will always be *another* high water in the same day, preceding or following that which we have mentioned by 12 hours 20 minutes nearly. On those days, however, in which high water occurs within 20 minutes of noon, there is no other high water on the same civil day.

The interval between high water and moon's transit is variable.

(3.) On closer examination it will be found that the interval between the time of the moon's passage over the meridian and the time of high water varies sensibly with the moon's age. At new moon, full moon, first quarter, and third quarter, (or rather on the day following each of these phases,) the interval between the time of the moon's passage and the time of high water is nearly the same: but from new moon to first quarter, and from full moon to third quarter, the high water occurs earlier than would be inferred by using that same interval; and from first quarter to full moon, and from third quarter to new moon, it occurs later than the same interval would give it.

Spring and Neap Tides.

(4.) If the observer examines the height of the water, he will find that the height at high water and the depression at low water are not always the same. On the days following new moon and full moon, high water is higher and low water lower than at any other time: these are called *Spring Tides*. On the days following the first and third quarters, high water is lower and low water higher than at any other time: these are called *Neap Tides*. The whole variation of height at spring tides is nearly double that at neap tides. There are other variations of height depending on other circumstances; but they require, for the most part, very numerous observations to establish the fact of their existence, and to give a measure of their amount. In many places, however, the tide which occurs at one certain part of the day (the afternoon for instance) is, during one half of the year, sensibly higher than the other tide which occurs upon the same day, and, during the other half of the year, sensibly lower.

The duration of the fall is longer than the duration of the rise.

The water continues to run up the river after high water.

(5.) Upon examining the circumstances of a single tide, the following facts will attract notice. The interval from high water to low water is greater than that from low water to high water: the difference between these intervals is sensibly greater at spring tides than at neap tides. The current in the river runs upwards for some time after high water, and after changing its direction, continues to run downwards for some time after low water, when it again changes its direction and runs upwards. This phænomenon is often so much misrepresented in the language of nautical men, that the mistake deserves particular notice. From the habit of observing tides in places where the current ceases at high water and at low water, sailors conceive that high water may always be inferred from the cessation of the current; and therefore it is not unusual for persons on the banks of the Thames to say that "it is high water in the centre of the channel long after it is high water at the shore." The observer who is not convinced of the absurdity of supposing the water in the middle of the channel to stand at one time considerably higher and at another time considerably lower than at the shore, will satisfy himself most easily as to the general fact by stationing himself at one of the central piers of a bridge, (as London Bridge,) when he will see that the water continues to run upwards even after its surface has dropped nearly two feet.

(6.) Now suppose that the observer examines the state of the tide in different parts of the same river. Commencing with the mouth of the river, (for instance Margate or Sheerness on the Thames, or Swansea or Cardiff on the Severn,) he will find that there is very little difference, or perhaps none which is appreciable, between the interval from high water to low water, and that from low water to high water. He will also find that the current runs up the channel for a long time (sometimes approaching to three hours) after high water, and runs down the channel for as long a time after low water. In going up the river, he will find that the time of high water occurs later and later, but yet that the velocity with which high water travels up the river is so great as entirely to banish the idea of explaining the Tide by supposing the same mass of water to have been moved all the way up the river. For instance, if at Margate the high water occurs on a certain day at twelve o'clock, it will occur at Sheerness at 24 minutes past one, at Gravesend at 15 minutes past two, and at London Bridge at a few minutes before three; having thus described in less than three hours a course of about 70 miles. He will also find that the interval from low water to high water diminishes as he goes up the river: thus, on the lower parts of the Severn, the rise and fall occupy little more than six hours each; but at Newnham on the Severn the whole rise of the water is effected in an hour and a half, the descent occupying nearly eleven hours. In cases like the last-mentioned, the first rise of the tide is sudden, and if the banks of the river are shoaly, the water spreads over the flat sands with a roaring surf, which travels rapidly up the river, presenting the phænomenon called a *bore* or *boar*, (sometimes *bour's-head*,) in French *barre* or *mascaret*. In other cases, however, when the difference of durations of rise and fall is considerable, there are in each high water two, or sometimes three distinct rises and falls of the water. The phænomena of bore and double tide are always much more conspicuous in spring tides than in neap tides.

(7.) If the estuary or mouth of the river contracts very much, the elevation and depression of the water will become very great. Thus at the entrance of the Bristol Channel the whole rise at spring tides is about 18 feet, at Swansea about 30 feet, and at Chepstow about 50 feet. Similar high tides occur at St. Malo and other parts of the great bay formed on the northern coast of France by the projection of land towards Cherbourg, and tides still higher in the head of the Bay of Fundy (Baie Française) on the Eastern coast of North America. But when the tide has fairly entered a river, its range of elevation and depression generally diminishes. Thus at Newnham, on the Severn, the range is reduced to about 18 feet, and it is still less at Gloucester.

(8.) Quitting now the phænomena of river-tides; if observations are made in a bay communicating with the open sea, the results will be found to be much more simple. The water will rise during 6 hours 10 minutes and will fall during an equal time; the whole rise and fall will usually be less than in rivers; a very slight current will be directed towards the head of the bay during the rise, and from it during the fall of the water. The variations of spring and neap tides, and the relation of the time of high water to the time of the moon's passage over the meridian, follow the same general laws as in rivers.

(9.) In long and narrow seas (for instance the English Channel) the tide in mid-channel follows the same laws as at a station near the mouth of a river, rising and falling in equal times, and running in a direction which may be considered analogous to the direction up a river, for three hours before and three hours after high water; and in the opposite direction, for three hours before and three hours after low water. But near the sides of the channel, and especially near the mouths of bays or estuaries branching from the channel, the change of tide follows a very peculiar law. The water is never stationary, as in river-tides, when changing from flow to ebb, but the direction of the current changes in 12 hours 20 minutes through all the points of the compass. As a general rule, supposing the observer's face turned in the direction which is analogous to the direction up a river; near the shores on his left hand the course of the tide-current revolves in the same direction as the hands of a watch, and near the shores on the right hand it revolves in the opposite direction. Near the headlands which separate different bays, there is usually, at certain times of the tide, a very rapid current, called a *race*.

(10.) The elevations and depressions of tides in the open seas are much smaller than in contracted seas or rivers, sometimes not exceeding one or two feet; the stream of the tide is generally insensible.

(11.) In seas of small extent (as the Mediterranean) the Tide is nearly insensible.

(12.) In some circumstances, phænomena which are scarcely perceptible in ordinary localities become paramount. Thus, in some positions near Behring's Straits, the difference of morning and evening tides, which is scarcely sensible in England, becomes so great that, in certain parts of the lunation, there appears to be only one tide in the day. Other phænomena peculiar to these localities, but less obvious to ordinary observation, will be noticed hereafter.

(13.) The phænomena which we have described must necessarily, for the most part, have been remarked by all nations dwelling on the borders of the ocean. Thus Cæsar, in his account of the invasion of Britain, (*De Bello Gallico*, lib. iv.) alludes to the nature of spring tides as perfectly well understood in connection with the moon's age. Some of the peculiarities of river tides, however, were not published in scientific works till the beginning of the last century; and some of the properties of the tides in the English and other channels were not known till the end of that century. Upon the whole, the statement above may be supposed to represent pretty well all that was known of the Tides about the year 1800: and it will serve to point out to the reader the leading facts, to whose explanation a Theory of the Tides ought to be directed. In the present century, the elaborate discussions of immense collections of accurate tide-observations by M. Laplace, Sir John W. Lubbock, and Professor Whewell, have brought to light and reduced to law many irregularities which were before that time unknown. We prefer, however, delaying the particular mention of these until we have discussed the various forms in which theory has been put for the purpose of explaining the grand facts of the Tides.

SECTION II.—EQUILIBRIUM-THEORY OF TIDES.

Inadequacy of all theories of the Tides, and the cause of it.

(14.) Before entering upon either of the theories explaining the Tides, we must allude to their inadequacy, perhaps not to the *explanation* of the facts already observed, but certainly to the *prediction* of new ones. This inadequacy does not appear to arise from any defect in the principles upon which the theory is based, (although perhaps our ignorance of the laws of friction among the particles of water, and between water and the sides of the channels which contain it, may be considered a failure of this kind,) but from the extreme difficulty of investigating mathematically the motions of fluids under all the various circumstances in which the waters of the sea and of rivers are found. For the problem of the Tides, it is evident, is essentially one of the *motion* of fluids. Yet so difficult are the investigations of motion that, till the time of Laplace, no good attempt was made to determine, by theory, the laws of the Tides, except on the supposition that the water was *at rest*. Since that time theories of *motion* have been applied; and it is hoped that in the present Treatise it will be found that something has been added to the preceding investigations of motion, possessing in some degree a practical character. Yet the theory, even in this state, reaches very few cases. Indeed, throughout the whole of this subject, the selection of the proper theoretical ground of explanation is a matter of judgment. In some cases we may conceive that we are justified in using the Equilibrium-theory; in others the Wave-theory will apply, completely or partially; in a few cases, the results of observation in one locality will be considered as a fundamental set of experiments, upon which the explanation of the phænomena in other localities will be grounded without further reduction to theory; and as a last resource, in almost every case, we shall be driven to the same arbitrary suppositions which Laplace introduced. Nevertheless, we conceive that our mathematical theory, pursued into some degree of detail, will be far from useless. In the instances which it does not master completely, it will show that there are ample grounds for the arbitrary alterations of constants introduced by Laplace in his suppositions, to which we have more than once alluded. It will show that we are precluded from further advance, partly by our almost necessary ignorance of the forms of the bottom in deep seas, and partly by the imperfection of our mathematics. It will leave no doubt whatever that the first principles of our explanation are correct. Begging the reader to receive the first part of this paragraph as an apology on the part of mathematicians for applying to the motion of Tides a theory so evidently inadequate as the Equilibrium-theory, we shall now proceed to give that theory, nearly in the terms of its proposers.

Popular explanation of equilibrium-theory.

(15.) The popular explanation of the Equilibrium-theory is very simple. If we conceive the earth to be covered wholly or in a great degree with water, and consider that the attraction of the moon upon different particles (according to the law of gravitation) is inversely as the square of their distance, and is therefore greatest for those particles which are nearest to it: then it will be obvious that the moon attracts the water on that side which is next to her, more than she attracts the great mass of the earth, and therefore tends to raise the water from the earth on the side next to her; but she also attracts the great mass of the earth more than she attracts the water upon the side most distant from her, and therefore tends to draw the earth from the water on the side most distant from her; which will produce exactly the same effect as if a force tended to draw the water away from the earth on that side. Thus the moon's action tends to raise the water on two opposite sides of the earth; and similarly the sun's action tends to raise the water on two opposite sides. The close relation, however, which the times of high water bear to the times of the moon's passage, shows that the moon's influence in raising the tides must be much greater than the sun's. If the sun and moon are together, as seen from the earth, the elevations produced by these two bodies will coincide in place, and will therefore be added together. Thus Spring Tides will be produced. In other relative positions of the sun and moon, it may happen that the elevation produced by the sun will occur at a place where the moon causes depression: the action of the sun there tends to counteract that of the moon, and Neap Tides will be produced.

Newton's first theory of the motion of the sea.

(16.) The theory of Newton is rather a collection of hints for a theory than any thing else. In the *Principia*, lib. I. prop. 66, cor. 19, he has (by a remarkable deduction from the Lunar Theory) considered the motion of water in a canal passing round the earth in or near to the earth's equator, and has arrived at the singular conclusion that the water would be lowest in that part which is most nearly under the body (the sun or moon) whose attraction causes the motion of the water. This conclusion we shall find to be entirely supported by more complete investigations. In lib. III. prop. 24, he has modified this conclusion, and seems to suppose that in free seas the high water ought to follow the moon's transit over the meridian (conceiving, for the moment, the moon's attraction to be the sole exciting cause of the Tides) in three hours, or at least in less than six hours. To this he appears to have been led by erroneous reasoning of the same kind as that which, in lib. I. prop. 66, cor. 20, has introduced an incorrect inference as to the Solar Nutation of the Earth's axis. We shall find hereafter that the introduction of friction into our theories of the motion of water will lead to a conclusion somewhat similar. The only part in which he uses numerical calculation is in lib. III. prop. 36, and 37, the subjects of which are, "*Invenire vim Solis ad Mare movendum*," "*Invenire vim Lunæ ad Mare movendum*." The following is his method of computation (the demonstration of the different parts of which we defer till we treat of the more complete theory of Bernoulli). First he refers to the Lunar Theory for a calculation of the force which the sun exerts to draw the moon, when in quadratures, towards the earth, and he finds it to be $\frac{1}{638092}$ part of gravity at the earth's surface. Then he remarks that the similar force upon the water at the earth's surface, in the position distant 90° of terrestrial arc from the point to which the sun is vertical, is less than the force upon the moon, in the proportion in which the water's distance from the centre of the earth is less than the moon's distance from the centre of the earth, or in the proportion of 1 : 60·5: and therefore the force which depresses the water, at the points 90° distant from those vertically under the sun, is $\frac{1}{38604600}$ of gravity. Then he observes that, in the points which are under the sun and opposite to the sun, the disturbing force of the sun tends to raise the water, and is twice as great as the depressing force already found. He then considers that the same general effect will be produced if we put away the depressing force entirely, and augment the elevating force by the same quantity, and thus we may consider that the sole cause of the disturbance of the water is an elevating force, at the point under the sun and the point opposite to the sun, equal to $\frac{1}{12868200}$ of gravity; the elevating force in other points being proportional to the versed sine of double the sun's altitude above the horizon of any point. In order to compute the effect of this force in raising the water, he compares this force with the centrifugal force ($\frac{1}{289}$ of gravity) at the earth's equator, produced by the diurnal rotation of the earth; it is therefore $\frac{289}{12868200}$ of the centrifugal force at the equator. Then, having found from his theory of the Figure of the Earth (supposed homogeneous) that the centrifugal force would raise the fluids at the equator 85820 Paris feet, and supposing the proportion of the elevations produced by the tidal force and the centrifugal force to be the same as the proportion of those forces, he obtains this result, that the action of the sun would raise the water, in the parts immediately under it and opposite to it, by 1 foot 11¼ inches Paris measure, or a little more than 2 feet English. Of the various steps of this process we shall here observe only that, though indirect, they are correct; and that the result (on the supposition of the earth's being homogeneous, and without rotation) represents correctly the elevation which the sun's action would produce.

Newton's calculation of the force of the Sun.

(17.) In order to ascertain the effect which the moon's action would produce, it is necessary to know the mass of the moon. For this there were in Newton's time no direct means: and he was, therefore, obliged to refer to the phænomena of the Tides themselves, as observed in places where, from local causes, the rise of the tide is very considerable. He quotes the observations of Sturmy on the tides in the Severn, at the mouth of the Avon, which give 45 feet for equinoctial spring tides, 25 feet for equinoctial neap tides: and those of Colepresse, on the tides at Plymouth, which give 16 feet for the mean height (intermediate between spring and neap) and 9 feet difference between springs and neaps. Preferring the proportion deduced from the former, he considers the height of equinoctial spring tides to be to that of equinoctial neap tides as 9 : 5. These tides (as will be seen hereafter) are in one case the effect of the moon augmented by the effect of the sun; and in the other case the effect of the moon diminished by that of the sun. If no correction were needed, we should infer at once that the power of the moon is to that of the sun as 7 : 2. But Newton remarks, that the greatest tides at Bristol do not happen till 43 hours after syzygies, "*ob aquarum reciprocos motus*," meaning, probably, that the oscillations, like the oscillations of a pendulum, have a kind of inertia, which (on purely mechanical principles) prevents them from attaining their greatest magnitude till the force which causes them has past its greatest magnitude. This we shall find, when we treat of Waves, to be incorrect, except we take account of friction. Assuming this, however, Newton proceed

His modified theory of motion.

to correct for the position of the luminaries *at the instant* of Bristol high tide: remarking that, as the sun is $18\frac{1}{4}$ degrees from the moon at spring tides, and $90°\pm18\frac{1}{4}°$ at neap tides, it is not the whole force of the sun which in one case increases and in the other case diminishes the moon's effect, but the whole force of the sun × cos 37°: and also that, as the moon's declination, 43 hours after an equinoctial syzygy, is about 22°, it is not the whole force of the moon that is concerned, but the whole force of the moon × $\cos^2 22°$. These corrections appear to us inconsistent with what has gone before: for if the tides are increasing from the accumulated action of the sun and moon during a long time, it seems clearly inaccurate to correct the results of observation for the places of those bodies at the very instant of observation. Then he observes that the moon is not, at syzygies, at her mean distance. All corrections applied, he finds that the force of the moon is to that of the sun as 4·4815 to 1: and, therefore, as the sun's force would raise the water 1 foot, $11\frac{1}{2}$ inches, the moon's force would raise it 8 feet, 8 inches. This, he remarks, is amply sufficient to account for all the motions of the tides.

(18.) The proportion of the moon's tidal force to the sun's tidal force is used by Newton (as a different value found in nearly the same manner has been used by Laplace) as the basis on which he calculates the moon's mass for application to other parts of the theory of gravitation. We shall see grounds hereafter for questioning the propriety of this calculation.

(19.) Assuming that Newton intended here (as he has done in several parts of Optics) only to exhibit, as far as he was able, grounds for a numerical calculation relating to the subject of Tides, but not bearing directly upon any of its specific phænomena, we must allow that (in spite of the apparent inconsistency of his corrections) it is a wonderful first attempt. That it had no further meaning will be sufficiently evident, not only from the proposition already cited, lib. I., prop. 66, cor. 19, but also from an examination of his 24th proposition of the third book, and the first corollary of his 27th proposition. In these he has treated the general explanation of the Tides as a matter of Wave-theory entirely, (though not without errors,) particularly in regard to the interference of semidiurnal tides, and in explaining the small rise and fall at some islands in the open sea by the oscillation of the whole mass of water between the bounding continents. As a philosopher, we conceive Newton to have shown himself here superior to his successors.

(20.) In explaining the more complete equilibrium-theory, we shall not confine ourselves to the methods of Daniel Bernoulli, or any other writer, but shall present the theory in the form which appears most convenient. The problem which we shall conceive to be presented to us for solution is this: suppose the earth to be a spherical solid nucleus, either homogeneous, or consisting of a series of spherical concentric strata, (each stratum having the same density and the same thickness in its whole extent,) which nucleus is covered with water: and suppose the disturbing forces of the sun and moon to act upon the water: to find the shape which the water will assume.

Tides and Waves.

Tides the same on a spherical earth as on a spheroid.

(21.) We have designedly used the word *spherical* for the form of the earth, because the investigation of the alteration produced in the form which, if undisturbed, would be spheroidal, would prove rather troublesome, and would lead to no result which we shall not obtain without it. As the earth's ellipticity is small, (the difference between its major axis and its minor axis being only about $\frac{1}{300}$ of either,) and as the whole elevation of the water, on the equilibrium-theory, is but a few feet, the reader will have no difficulty in comprehending that the tidal elevation of the water on the spheroid, though without doubt theoretically different from that on a sphere, will practically differ by a quantity which is quite insensible. In the same manner the reader will understand that, supposing the water to be disturbed by the action of the sun, and supposing the action of the moon to be then introduced, the additional disturbance which it will cause will be (as far as the senses can discover) the same as it would have caused if it had acted on water not disturbed by the action of the sun. And thus the whole disturbance which the two luminaries will produce upon the water surrounding a spheroidal nucleus will be found with sufficient accuracy by investigating the disturbance which each of them, separately considered, would produce in the water surrounding a spherical nucleus, and by adding those two disturbances together.

The tide produced by each of the attracting luminaries the same as if the other did not exist.

(22.) Our first effort will now be directed to the estimation of the disturbing force of the sun upon the water. We shall use the following notation:—

K, the mean density of the earth's spherical nucleus: R, its radius.

k, the density of the water: r, the radius of the external spherical surface of the water when undisturbed by the sun and moon.

(The density is supposed to be estimated by the acceleration which a cubical unit of matter acting by its attraction during a unit of time will produce in a body whose distance is the unit of distance: the velocity and acceleration being referred to the same units.)

E, the whole mass of the earth and water.

g, the numerical expression, referred to the same units, for the acceleration which gravity at the earth's surface causes in bodies falling freely.

x, y, z, the rectangular coordinates of any point in the fluid, the centre of the spherical nucleus being the origin, and z being parallel to the line joining the centres of the sun and the earth.

D, the sun's distance: D_m, the sun's mean distance: P, the sun's parallax: P_m, the sun's mean parallax: T, the periodic time of the earth's revolution round the sun, or the length of a sidereal year: S, the sun's mass, estimated by the acceleration which it will produce (in the same manner as for the density, above).

D′, the moon's distance: D'_m, the moon's mean distance: P′, the moon's parallax: P'_m, the moon's mean parallax: T′, the periodic time of the moon's revolution round the earth: M, the moon's mass.

Actual forces of the Sun upon any particle of the water.

(23.) The distance of the sun from the point whose co-ordinates are x, y, z, is $\sqrt{\{x^2+y^2+(D-z)^2\}}$, and the attraction of the sun upon that point, according to the law of gravitation, is $\frac{S}{x^2+y^2+(D-z)^2}$. This force is in the direction of the line drawn from the point in question to the sun. Our expression for this force supposes it to be estimated as an accelerating force; the statical pressure which corresponds to it may be resolved into three pressures in the directions of x, y, z; and, by the principle that accelerations of a given particle are proportional to the pressures which cause them, the accelerating forces which act in these directions may be deduced from the given accelerating force by the same laws of resolution as those for statical pressures. Thus we find for the resolved parts of the sun's accelerating force on the particle in question,

$$\text{In the direction of } x \qquad \frac{-Sx}{\{x^2+y^2+(D-z)^2\}^{\frac{3}{2}}}$$

$$\text{In the direction of } y \qquad \frac{-Sy}{\{x^2+y^2+(D-z)^2\}^{\frac{3}{2}}}$$

$$\text{In the direction of } z \qquad \frac{S(D-z)}{\{x^2+y^2+(D-z)^2\}^{\frac{3}{2}}}.$$

Expansions of the expressions.

(24.) Now the proportion of the earth's radius to the distance of the sun is extremely small; and the value of $\frac{x}{D}$, $\frac{y}{D}$, or $\frac{z}{D}$, is necessarily smaller. It will be allowable, therefore, to expand these expressions approximately, retaining no higher powers of x, y, z, than the second. (Indeed these latter terms are wholly insensible for the sun; and we retain them only because, in the expressions which we shall infer by analogy for the forces of the moon, they may be considered sensible.) With this restriction, observing that

$$\frac{1}{\{x^2+y^2+(D-z^2\}^{\frac{3}{2}}}=\frac{1}{D^3}\left\{1-\frac{2z}{D}+\frac{x^2+y^2+z^2}{D^2}\right\}^{-\frac{3}{2}}=\frac{1}{D^3}\left\{1+\frac{3z}{D}+\frac{12z^2-3x^2-3y^2}{2D^2}\right\},$$

we have

$$\text{Sun's force in the direction of } x=\frac{-Sx}{D^3}-\frac{3Sxz}{D^4}$$

$$\text{Sun's force in the direction of } y=\frac{-Sy}{D^3}-\frac{3Syz}{D^4}$$

$$\text{Sun's force in the direction of } z=\frac{S}{D^2}+\frac{2Sz}{D^3}+\frac{S(6z^2-3x^2-3y^2)}{2D^4}.$$

Disturbing forces of the Sun upon every particle.

(25.) These expressions represent the *whole* force of the sun upon any particle. But it is evident that, to find the force which disturbs the form of the water in reference to the position of the earth, we must not use the *whole* force of the sun upon any particle, but the *excess* of the sun's force on the particle *above* the sun's force on the centre of gravity of the earth. In order to find the sun's force on the centre of gravity of the earth, we must multiply each particle of the earth by the force which acts upon it; we must add together all these products, and we must divide the sum by the sum of all the particles of the earth. Now, using the expressions above, (which apply to the earth as well as to the water,) we may easily see that, if we multiply each particle of the earth by the force $\frac{-Sx}{D^3}$, and add all the products together, the sum will be 0, because for every particle which has a certain positive value of x there will be another particle having an equal negative value of x, and their products will, when added, destroy each other. The same remark applies to the terms depending on y, z, xz, and yz. But it does not apply to the term $\frac{S}{D^2}$ or to that depending on x^2, y^2, and z^2.

(26.) Now for the term $\frac{S}{D^2}$ we have only to remark that, upon multiplying it by each of the particles, adding all the products, and dividing the sum by the sum of the particles, we again obtain $\frac{S}{D^2}$. For the other terms we may proceed thus:—The sum of all the products of each particle by its value of z^2, throughout the sphere, will be the same as the sum of the products of each particle by its value of x^2 or y^2, because, supposing the sphere at one time divided by planes perpendicular to z, and at another time by planes perpendicular to x or y, the sections for similar values of x, y, or z, will be similar. The sum, therefore, for $6z^2$ will be equal to that for $3x^2+3y^2$, and, therefore, that for $6z^2-3x^2-3y^2$ will be 0. The only remaining term, therefore, for the sun's force on the centre of gravity of the earth, is $\frac{S}{D^2}$, in the direction of z.

(27.) Subtracting this term, therefore, from the force in the same direction upon the particle under consideration, we have the following expressions for the sun's disturbing force,

$$\text{In the direction of } x \qquad \frac{-Sx}{D^3}-\frac{3Sxz}{D^4}$$

$$\text{In the direction of } y \qquad \frac{-Sy}{D^3}-\frac{3Syz}{D^4}$$

In the direction of z $\qquad -\frac{+2Sz}{D^3}+\frac{S(6z^2-3x^2-3y^2)}{2D^4}$

Sect. II. Equilibrium Theory of Tides.

The density of the fluid supposed insignificant. Mathematical condition which determines the form of the fluid when in equilibrium.

(28.) We shall now proceed to investigate the form which the water covering the solid nucleus will receive from the action of these forces in addition to the attraction of the nucleus and the mutual attraction of the particles of water. And first we may remark that, if the attraction of the particles of the water is insensible, (or if the density of the water is insensible in comparison with that of the nucleus,) the problem is very simple. Referring to our Treatise on the FIGURE OF THE EARTH, section 2, article 7., we find that the condition for the possibility of equilibrium of the water is that $Xdx+Ydy+Zdz$ shall be a complete differential, or, in more correct language, that it shall be possible for us to find some function U, such that $\frac{dU}{dx}=X$, $\frac{dU}{dy}=Y$, $\frac{dU}{dz}=Z$; X, Y, Z, being the whole forces in the directions of x, y, z. In article 9. of the same Treatise it is shown that, when the forces are produced by attraction to any number of particles, this condition is always satisfied; and, therefore, it is satisfied here (which will also be easily seen on substituting the expressions which we shall immediately exhibit). In article 8. of the same Treatise, it is proved that the form of the external surface will be determined by making $Xdx+Ydy+Zdz=0$, or $U=C$. To apply this now, we must add, to the expressions above, the resolved parts of the attraction of the nucleus. That attraction is the same as if all the matter of the nucleus were collected at its centre; and it is, therefore, $\frac{4\pi}{3}\cdot\frac{R^3K}{x^2+y^2+z^2}$. The resolved parts in the directions of x, y, z, are respectively

$$-\frac{4\pi}{3}\cdot\frac{R^3Kx}{(x^2+y^2+z^2)^{\frac{3}{2}}},\qquad -\frac{4\pi}{3}\cdot\frac{R^3Ky}{(x^2+y^2+z^2)^{\frac{3}{2}}},\qquad -\frac{4\pi}{3}\cdot\frac{R^3Kz}{(x^2+y^2+z^2)^{\frac{3}{2}}}.$$

Hence the whole forces acting on any particle of the water are

$$\frac{dU}{dx}=X=-\frac{4\pi}{3}\cdot\frac{R^3Kx}{(x^2+y^2+z^2)^{\frac{3}{2}}}-\frac{Sx}{D^3}-\frac{3Sxz}{D^4}$$

$$\frac{dU}{dy}=Y=-\frac{4\pi}{3}\cdot\frac{R^3Ky}{(x^2+y^2+z^2)^{\frac{3}{2}}}-\frac{Sy}{D^3}-\frac{3Syz}{D^4}$$

$$\frac{dU}{dz}=Z=-\frac{4\pi}{3}\cdot\frac{R^3Kz}{(x^2+y^2+z^2)^{\frac{3}{2}}}+\frac{2Sz}{D^3}+\frac{S(6z^2-3x^2-3y^2)}{2D^4}.$$

From these we easily find

$$U=\frac{4\pi}{3}\cdot\frac{R^3K}{(x^2+y^2+z^2)^{\frac{1}{2}}}+\frac{S(2z^2-x^2-y^2)}{2D^3}+\frac{S(2z^3-3x^2z-3y^2z)}{2D^4}$$

Equation to the surface of the water.

and the equation to the external surface of the water will therefore be

$$C=\frac{4\pi}{3}\cdot\frac{R^3K}{(x^2+y^2+z^2)^{\frac{1}{2}}}+\frac{S(2z^2-x^2-y^2)}{2D^3}+\frac{S(2z^3-3x^2z-3y^2z)}{2D^4}.$$

We may remark, that the very same equation would have been obtained if we had considered only the disturbing force which acts in the direction of a tangent to the Earth's surface. For, the equation which we have used for the external surface amounts to this, that the whole force is perpendicular to the external surface. Therefore the inclination of the surface of the water to the surface of the sphere will depend entirely on the proportion of the tangential force to the force directed towards the centre of the sphere. The only tangential force is the tangential disturbing force, which must therefore be retained; but the force directed to the centre of the sphere consists of the attraction of the sphere and the minute disturbing force; and it is indifferent, for the inclination of which we have spoken, whether we retain that minute portion or not. If we retain it, we consider all the forces; if we omit it, we use no disturbing force but that which is tangential. We shall see hereafter that a similar rule is true when we consider the forces producing the *motion* of the sea.

Expansion supposing the form to differ little from a sphere

(29.) Since the difference of the form from a spherical form will be exceedingly small, we may for $(x^2+y^2+z^2)^{\frac{1}{2}}$, which is the distance of any point at the surface from the sphere's centre, put $r+q$ (then q is the elevation of the water above the height which it would have had if undisturbed by the attraction of the sun): and in substituting this expression in the first term on the right hand side of the equation we may neglect the square of q; and in substituting it in the factors of the other terms, which are exceedingly small, we may omit q entirely. In these small terms, therefore,

$$2z^2-x^2-y^2=2z^2-(r^2-z^2)=3z^2-r^2,$$

$$z(2z^2-3x^2-3y^2)=z\{2z^2-3(r^2-z^2)\}=z(5z^2-3r^2);$$

and in the larger term

$$\frac{1}{(x^2+y^2+z^2)^{\frac{1}{2}}}=\frac{1}{r+q}=\frac{1}{r}-\frac{q}{r^2}.$$

Substituting, the equation becomes

$$C=\frac{4\pi}{3}R^3K\left(\frac{1}{r}-\frac{q}{r^2}\right)+\frac{S(3z^2-r^2)}{2D^3}+\frac{Sz(5z^2-3r^2)}{2D^4},$$

or

$$q=r-\frac{3r^2C}{4\pi R^3K}+\frac{3r^2}{4\pi R^3K}\left\{\frac{S(3z^2-r^2)}{2D^3}+\frac{Sz(5z^2-3r^2)}{2D^4}\right\};$$

which will be more conveniently written

$$q=C'+\frac{3r^2}{4\pi R^3K}\left\{\frac{S(3z^2-r^2)}{2D^3}+\frac{Sz(5z^2-3r^2)}{2D^4}\right\}.$$

(30.) In order to determine the value of C′, we must observe that the whole volume included within the external surface of the water is equal to the sphere whose radius is r, and therefore if we estimate the sum of all the quantities of water which are raised above the surface of the sphere, (depressions below the surface being considered negative,) that sum will $=0$. Now conceive that there is traced upon the surface of the sphere a series of circles at small distances, resembling the parallels of a terrestrial globe, the poles of all the circles being at the point which is nearest to the sun, or z having the same value through the whole circumference of each circle. Let θ be the angle made by the axis of z with the line drawn from the centre of the sphere to any point of one of these circles, $\theta+\delta\theta$ the similar angle for the next circle. The surface of the sphere included between these two circles will $=2\pi.r\sin\theta.r\delta\theta$ nearly, and therefore the volume of water elevated above that ring upon the sphere $=2\pi.q.r^2\sin\theta.\delta\theta$ nearly; which, since $z=r\cos\theta$, is $=-2\pi qr.\delta z$ nearly. We have, therefore, to find the sum of all the values of

$$-2\pi C'r\,\delta z-\frac{3r^3}{2R^3K}\left\{\frac{S(3z^2-r^2)}{2D^3}+\frac{S(5z^3-3rz)}{2D^4}\right\}\delta z,$$

or to find

$$-\int_z 2\pi C'r-\frac{3r^3}{2R^3K}\int_z\left\{\frac{S(3z^2-r^2)}{2D^3}+\frac{S(5z^3-3r^2z)}{2D^4}\right\}$$

Expression for the elevation of the water.

through the whole extent of the sphere; that is, between the limits $z=-r$, $z=+r$. The value of this integral is $-4\pi C'r^2$. Making this $=0$, we have $C'=0$, and therefore

$$q=\frac{3r^2}{4\pi R^3K}\left\{\frac{S(3z^2-r^2)}{2D^3}+\frac{Sz(5z^2-3r^2)}{2D^4}\right\},$$

or

$$=\frac{3r^4}{4\pi R^3K}\left\{\frac{S}{2D^3}(3\cos^2\theta-1)+\frac{r}{D}.\frac{S}{2D^3}.\cos\theta\,(5\cos^2\theta-3)\right\}.$$

(31.) In order to put this expression into a form adapted to numerical computation, we must deliver it from the quantities K and S. First, to remove K: since $\frac{4\pi R^3}{3}$ is the volume of the nucleus, $\frac{4\pi R^3K}{3}$ is its mass, expressed by the acceleration which it would cause at distance 1, as we have assumed in (22.); and, therefore, $\frac{4\pi R^3K}{3r^2}$ is the acceleration which it would cause at the surface of the water; but this acceleration, being that of ordinary falling bodies, is expressed by g: therefore $\frac{3r^4}{4\pi R^3K}=\frac{r^2}{g}$. Secondly, to remove S. In our treatise on Physical Astronomy, page 655, equation (24.), it is shown that $T=\frac{2\pi.a^{\frac{3}{2}}}{\sqrt{(M+m)}}$; which will be expressed in the notation of this Treatise if we remark that a is the mean distance of the revolving body $=D_m$; and that $M+m$ is the sum of the masses of the two bodies, which, as the earth is very small in comparison with the Sun, wiil not sensibly differ from S. T is the periodic time $=1$ year. Thus $T=\frac{2\pi.D_m^{\frac{3}{2}}}{\sqrt{S}}$, or $\frac{S}{D_m^3}=\frac{4\pi^2}{T^2}$; and therefore, $\frac{S}{D^3}=\left(\frac{D_m}{D}\right)^3.\frac{4\pi^2}{T^2}$. Also $\frac{r}{D}=\sin P$. Thus the expression for q becomes

Elevation expressed in a form fit for calculation.

$$\frac{2\pi^2r^2}{T^2g}.\left(\frac{D_m}{D}\right)^3.\{3\cos^2\theta-1+\sin P.\cos\theta.(5\cos^2\theta-3)\}.$$

This expression is in a form entirely fit for calculation; it is only necessary to remark that the same units must be used throughout: thus, if g expresses the acceleration in inches produced by gravity in one second of time, r must be expressed in inches, and T in seconds of time. To avoid the introduction of very large numbers, we may make use of the elements of the moon's motion. The same equation of Physical Astronomy (neglecting the perturbations of the moon) gives us $T'=\frac{2\pi.D'^{\frac{3}{2}}_m}{\sqrt{\left(\frac{4\pi R^3K}{3}+M\right)}}$. Let the moon's mass be $\frac{1}{n}$ part of the earth's, or $M = \frac{1}{n} \cdot \frac{4\pi R^3 K}{3}$: then $T' = \frac{2\pi . D'^{\frac{3}{2}}_m}{\sqrt{\frac{4\pi R^3 K}{3}} \sqrt{\left(1+\frac{1}{n}\right)}}$; from which $\frac{3r^4}{4\pi R^3 K} = \frac{T'^2 \left(1+\frac{1}{n}\right) r^4}{4\pi^2 D'^3_m}$,

and

$$q = \frac{T'^2}{2T^2} \cdot \left(1+\frac{1}{n}\right) \cdot \frac{r^3}{D'^3_m} r \cdot \left(\frac{D_m}{D}\right)^3 . \{3\cos^2\theta - 1 + \sin P . \cos\theta \, (5\cos^2\theta - 3)\}$$

$$= \frac{n+1}{2n} \cdot \left(\frac{T'}{T}\right)^2 . (\sin P'_m)^3 . r . \left(\frac{D_m}{D}\right)^3 . \{3\cos^2\theta - 1 + \sin P . \cos\theta \, (5\cos^2\theta - 3)\}.$$

If we suppose the moon's mass $\frac{1}{80}$ of the earth, and give the values commonly adopted for the other quantities, this becomes

$$\frac{81}{160} \cdot \left(\frac{27 \cdot 32}{365 \cdot 25}\right)^2 . (\sin 57' . 1'')^3 \times 20900000 \times \left(\frac{D_m}{D}\right)^3 . \{3\cos^2\theta - 1 + \sin 8'' \cdot 7 . \cos\theta \, (5\cos^2\theta - 3)\},$$

where the earth's mean semidiameter is expressed in English feet. Performing the numerical computation upon either of these expressions, the formula becomes

Calculation of the elevation of the water.

$$q = 0 \cdot 2710 \text{ foot} \times \left(\frac{D_m}{D}\right)^3 . \{3\cos^2\theta - 1 + \sin 8'' \cdot 7 . \cos\theta \, (5\cos^2\theta - 3)\},$$

or

$$= 0 \cdot 2710 \text{ foot} \times \left(\frac{D_m}{D}\right)^3 \times (3\cos^2\theta - 1),$$

the last part of the preceding formula being quite insensible.

(32.) Omitting for the present the consideration of the factor $\left(\frac{D_m}{D}\right)^3$, which never differs much from 1, we find that the greatest positive value of the formula (denoting elevation of the water) occurs when $\theta = 0$, or $\theta = 180°$, for which cases $3\cos^2\theta - 1 = 2$, and the elevation of the water $= 0 \cdot 542$ foot. Now θ is the angle contained between the line drawn from the earth's centre to the sun and the line drawn from the earth's centre to any point on the surface which is under consideration. Consequently, the value $\theta = 0$ belongs to that point of the earth's surface, or of the surface of the water, which is immediately under the sun; and the value $\theta = 180°$ belongs to that point of the surface of the water which is farthest from the sun. The sun's action, therefore, would raise the water 0·542 foot on that side which is next to the sun, and also on that side which is farthest from the sun.

Greatest elevation.

(33.) The greatest negative value of the formula (denoting depression of the water) occurs when $\theta = 90°$, for which case $3\cos^2\theta - 1 = -1$, and the depression of the water is 0·2710 foot. Now θ is $= 90°$ for all those parts of the surface of the water which are determined by making a plane to pass through the earth's centre perpendicular to the line joining the earth's centre with the sun. The sun's action, therefore, would depress the water 0·2710 foot in the zone, surrounding the earth, which is intermediate between the point under the sun and the point that is farthest from the sun.

Greatest depression.

(34.) It appears, therefore, that the elevation of the water produced by the sun on one part of the earth, where the elevation is greatest, is double of the depression produced on other parts where the depression is greatest. Suppose now that the water always assumes the form which we have found, and that the earth revolves within the coating of water. (This supposition, absurd as it is, is the only one upon which it is possible to apply the equilibrium-theory.) And suppose an observer to be stationed upon a small island projecting above the water, and to watch there the rise and fall of the surface of the water. To fix our ideas, suppose the earth's axis of revolution to be perpendicular to the line joining the sun and the earth, and suppose the observer to be at the earth's equator. Then, in the course of a revolution, he will be carried successively through the point which is nearest to the sun, through the zone intermediate between the point nearest to the sun and the point most distant from it, through the point most distant from the sun, again through the intermediate zone, and to the point which is nearest to the sun. He will, therefore, have been carried twice through the part where the elevation is greatest, and twice through the part where the depression is greatest. The greatest elevation, as we have found, is double of the greatest depression. From this circumstance many persons have imagined that, in all tides, under all local circumstances whatever, the line of mean water, or the line at which the surface of the water would stand if undisturbed by tidal action, is to be found by taking a line whose height above low water is one-third of the height of high water above low water; so that the elevation of high water above that line will be double the depression of low water below it. This (as we shall afterwards show) is inconsistent with the laws of Waves on deep water, upon which, without doubt, the phænomena of Tides depend entirely: but, moreover, it is inconsistent with the equilibrium-theory itself. For, to ascertain the *mean* height of the water, we must not suppose the sun and moon actually removed from

Elevation apparently double the depression.

Elevation above mean really equal to the depression below mean.

our system, but we must suppose an estimation to be made of the form which the water would assume under the action of their *mean* forces; and, considering this as the mean state of the water, we must compare the disturbed state with this, in order to ascertain the true value of the disturbance from mean state. Now the mean elevation of the water at our imaginary island, under the sun's mean action, will evidently be found by supposing the earth to turn uniformly round, by taking the actual elevation of the water in each momentary position, and by taking the mean of all those actual elevations. Putting A for the coefficient 0·2710 foot $\times\left(\frac{D_m}{D}\right)^3$, the elevation of the water, above the position which it would have had if no sun existed, is $A\,(3\cos^2\theta-1)$: and if the sphere turns uniformly round, θ will pass uniformly through all the values from 0 to 2π: we have, therefore, to find the mean of all the values of $A\,(3\cos^2\theta-1)$ when θ increases uniformly from 0 to 2π. Putting it under the form $A\left\{\frac{3}{2}(1+\cos 2\theta)-1\right\}$, or $A\left\{\frac{1}{2}+\frac{3}{2}\cos 2\theta\right\}$, and remarking that, while θ increases from 0 to 2π, $\cos 2\theta$ goes through equal positive and negative values, the mean is $\frac{A}{2}$. And this is the elevation of the water under the action of the sun's mean force. Subtracting this from the actual elevation, or $A\,(3\cos^2\theta-1)$, we have for the effect of the periodic tidal force $A\left(3\cos^2\theta-\frac{3}{2}\right)$. The greatest tidal elevation is found by making $\theta=0$, or 180°, or $\cos^2\theta=1$, and is therefore $A\times\frac{3}{2}$: the greatest tidal depression is found by making $\theta=90°$, or $\cos\theta=0$, which gives tidal elevation $=-A\times\frac{3}{2}$, or tidal depression $=A\times\frac{3}{2}$. The greatest tidal elevation, and the greatest tidal depression, are therefore equal, even on the equilibrium-theory.

Elevation produced by the moon.

(35.) We shall now proceed to investigate the effect of the moon upon the water, still supposing the density of the water to be insignificant in comparison with that of the earth. The expression of (30.), *mutatis mutandis*, will apply to the elevation produced by the moon: supposing here that θ' is the angle between the line drawn from the earth's centre to the point under consideration, and the line drawn from the earth's centre to the moon. Putting q' then for the elevation produced by the moon,

$$q'=\frac{3r^4}{4\pi R^3 K}\left\{\frac{M}{2D'^3}(3\cos^2\theta'-1)+\frac{r}{D'}\cdot\frac{M}{2D'^3}\cdot\cos\theta\,(5\cos^2\theta'-3)\right\}$$

To reduce this to calculation we must remark that $\frac{4\pi}{3}R^3K=$ earth's mass $=n\times M$; and therefore

$$\frac{3r^4}{4\pi R^3 K}\times\frac{M}{2D'^3}=\frac{r^4}{2n\,D'^3}=\frac{1}{2n}\cdot r\cdot\left(\frac{r}{D'_m}\right)^3\cdot\left(\frac{D'_m}{D'}\right)^3=\frac{1}{2n}\cdot r\cdot\left(\sin 57'.\ 1''\right)^3\cdot\left(\frac{D'_m}{D'}\right)^3.$$

The numerical value of this depends entirely upon the value of n, or the proportion of the earth's mass to the moon's. If (as we supposed before) $n=80$, and $r=20900000$ feet, the expression becomes

$$q'=\frac{20900000}{160}\left(\sin 57'.\ 1''\right)^3\cdot\left(\frac{D'_m}{D'}\right)^3\left\{3\cos^2\theta'-1+(\sin 57'.1'')\,\frac{D'_m}{D'}\cos\theta'.\ (5\cos^2\theta'-3)\right\}$$

$$=0\cdot5959 \text{ foot}\times\left(\frac{D'_m}{D'}\right)^3\times\left(3\cos^2\theta'-1\right)+0\cdot0100 \text{ foot}\times\left(\frac{D'_m}{D'}\right)^4\times\cos\theta'.(5\cos^2\theta'-3).$$

If we supposed the moon's mass to be $\frac{1}{40}$ of the earth, (which is very nearly the supposition of Newton,) the numerical coefficients would be respectively 1·1918 foot and 0·0200 foot. The phænomena of nutation (using the numbers in the FIGURE OF THE EARTH, page 235, and supposing $\frac{a}{b}=\frac{50\cdot3}{9\cdot25}$) give $n=82$.

Elevation a little greater on the side next to the moon than on the opposite side.

Whichever of these values of n, or of any intermediate to these two, we decide on adopting, it is clear that the last term of the formula is insignificant; its greatest numerical values, when $n=80$, being ± 0·02 foot. We shall therefore omit the consideration of it in future. We may remark that, theoretically considered, its meaning is that the water is raised a little higher on the side next to the moon than on the side most distant from the moon. For when $\theta'=0$, $\cos\theta'$ is positive, and the term $\cos\theta'\,(5\cos^2\theta'-3)$ is numerically added to $3\cos^2\theta'-1$, which is also positive: but when $\theta'=180°$, $\cos\theta'$ is negative, and the term $\cos\theta'\,(5\cos^2\theta'-3)$ is numerically subtracted from $3\cos^2\theta'-1$, which is positive. In the intermediate zone, $\cos\theta'=0$, and the height of the water is not altered by this term.

Investigation supposing the density of the water not insignificant.

(36.) We shall defer the examination of the effects of the variations of $\frac{D'_m}{D'}$, of the composition of the effects of the sun and moon, and of their positions in declination, &c., and shall proceed to investigate the elevation of the water on the supposition that the density of the water is not insignificant in comparison with that of the earth. The modification which this produces in the theory is, that the attraction of the water upon its own particles must be found. The problem now becomes very similar to that of the Figure of the Earth, and we shall solve it in the same way, namely, synthetically, by supposing the form to be spheroidal, and showing that, with proper proportion of the axes, the equations of equilibrium will be satisfied. For the developments of the formulæ requisite, we shall refer, for the most part, to the article on the FIGURE OF THE EARTH.

Method of conducting this investigation.

(37.) We shall assume, then, that the form of the external surface of the water is that of a prolate spheroid, its axis being directed to the sun (omitting, for the present, the forces of the moon). And we shall consider that the forces which act on the water are, the attraction of the spherical nucleus, the attraction of the water, whose interior boundary is spherical and whose exterior boundary is spheroidal, and the disturbing forces of the sun found in (27.). As the attractions of the particles of water, as well as all other attractions, satisfy the condition $X=\frac{dU}{dx}$, $Y=\frac{dU}{dy}$, $Z=\frac{dU}{dz}$, it will only be necessary for us to determine the forces which act on the particles at the surface, to find from them the expression for U, to form the equation $U=C$ for the exterior surface, and to try whether this equation can be made to coincide with the assumed spheroidal equation.

Attraction of an entire spheroid of water.

(38.) The attraction of the water upon a point at its surface will be found by subtracting the attraction of a bulk equal to the spherical nucleus from the attraction of the spheroid of water supposed entire. Let the semiaxis of the spheroid in the direction of z, or towards the sun, be b; the semiaxes at right angles to this (or in the plane of x, y,) $b(1-\zeta)$. Comparing this with the assumption in the FIGURE OF THE EARTH, sec. ii. art. 30., it is evident that the formulæ of article 32. of that treatise will apply here, if we put $-\zeta$ for ϵ, and omit the terms depending on centrifugal force. Thus we have, for the attraction of the watery spheroid supposed entire,

In the direction of x, $\quad -\frac{4\pi}{3}k\left(1+\frac{2}{5}\zeta\right)x$

In the direction of y, $\quad -\frac{4\pi}{3}k\left(1+\frac{2}{5}\zeta\right)y$

In the direction of z, $\quad -\frac{4\pi}{3}k\left(1-\frac{4}{5}\zeta\right)z.$

The attraction of a sphere of the same density whose radius is R would be

In the direction of x, $\quad -\frac{4\pi}{3}k\,R^3\frac{x}{(x^2+y^2+z^2)^{\frac{3}{2}}}$

In the direction of y, $\quad -\frac{4\pi}{3}k\,R^3\frac{y}{(x^2+y^2+z^2)^{\frac{3}{2}}}$

In the direction of z, $\quad -\frac{4\pi}{3}k\,R^3\frac{z}{(x^2+y^2+z^2)^{\frac{3}{2}}}.$

Attraction of the water covering the spherical nucleus.

Subtracting these from the former we obtain for the real attractions of the water,

In the direction of x, $\quad -\frac{4\pi}{3}k\left(1+\frac{2}{5}\zeta\right)x+\frac{4\pi}{3}k\,R^3\frac{x}{(x^2+y^2+z^2)^{\frac{3}{2}}}$

In the direction of y, $\quad -\frac{4\pi}{3}k\left(1+\frac{2}{5}\zeta\right)y+\frac{4\pi}{3}k\,R^3\frac{y}{(x^2+y^2+z^2)^{\frac{3}{2}}}$

In the direction of z, $\quad -\frac{4\pi}{3}k\left(1-\frac{4}{5}\zeta\right)z+\frac{4\pi}{3}k\,R^3\frac{z}{(x^2+y^2+z^2)^{\frac{3}{2}}}.$

Attraction of the nucleus of earth.

(39.) The attractions of the spherical nucleus of earth will be

In the direction of x, $\quad -\frac{4\pi}{3}KR^3\frac{x}{(x^2+y^2+z^2)^{\frac{3}{2}}}$

In the direction of y, $\quad -\frac{4\pi}{3}KR^3\frac{y}{(x^2+y^2+z^2)^{\frac{3}{2}}}$

In the direction of z, $\quad -\frac{4\pi}{3}KR^3\frac{z}{(x^2+y^2+z^2)^{\frac{3}{2}}}.$

Whole force which acts on the water.

Combining these with the attractions of the water found above, and with the sun's disturbing forces found in (27.), omitting the last terms of the latter, we have

$$X=-\frac{4\pi}{3}k\left(1+\frac{2}{5}\zeta\right)x-\frac{4\pi}{3}(K-k)\,R^3\frac{x}{(x^2+y^2+z^2)^{\frac{3}{2}}}-\frac{Sx}{D^3}$$

$$Y=-\frac{4\pi}{3}k\left(1+\frac{2}{5}\zeta\right)y-\frac{4\pi}{3}(K-k)\,R^3\frac{y}{(x^2+y^2+z^2)^{\frac{3}{2}}}-\frac{Sy}{D^3}$$

$$Z=-\frac{4\pi}{3}k\left(1-\frac{4}{5}\zeta\right)z-\frac{4\pi}{3}(K-k)\,R^3\frac{z}{(x^2+y^2+z^2)^{\frac{3}{2}}}+\frac{2Sz}{D^3}.$$

(40.) The equation $U=C$ becomes therefore

$$-\frac{4\pi}{3}k\left\{\frac{x^2+y^2+z^2}{2}+\zeta\,.\frac{x^2+y^2-2z^2}{5}\right\}+\frac{4\pi}{3}(K-k)\frac{R^3}{(x^2+y^2+z^2)^{\frac{1}{2}}}+\frac{S}{2D^3}(2z^2-x^2-y^2)=C$$

Equation to the surface deduced from the forces.

If we make $(x^2+y^2+z^2)^{\frac{1}{2}}=r+q$, and retain the first power of q, only in those terms which are not multiplied by ζ or $\frac{S}{2D^3}$, we obtain

$$-\frac{4\pi}{3}k\left\{\frac{r^2}{2}+rq+\zeta\frac{r^2-3z^2}{5}\right\}+\frac{4\pi}{3}\frac{(K-k)\,R^3}{r}-\frac{4\pi}{3}\frac{(K-k)\,R^3}{r^2}q+\frac{S}{2D^3}(3z^2-r^2)=C$$

or

$$q\times\frac{4\pi}{3}\left\{kr+\frac{(K-k)\,R^3}{r^2}\right\}=-\frac{4\pi}{3}k\frac{r^2}{2}+\frac{4\pi}{3}.\frac{(K-k)\,R^3}{r}-C+\left\{\frac{4\pi k}{15}\zeta+\frac{S}{2D^3}\right\}(3z^2-r^2).$$

The equation to the prolate spheroid is $\frac{x^2+y^2}{b^2(1-\zeta)^2}+\frac{z^2}{b^2}=1$, or $x^2+y^2+2\zeta(x^2+y^2)+z^2=b^2$. And the point now to be determined is, whether this equation can be made to coincide with that above. Putting $r+q$ for $(x^2+y^2+z^2)^{\frac{1}{2}}$, and omitting q in the term multiplied by ζ, this equation becomes

$$r^2+2r.q=b^2-2\zeta(x^2+y^2)=b^2+2\zeta(z^2-r^2)=b^2+\frac{2}{3}\zeta(3z^2-3r^2)=b^2-\frac{4}{3}\zeta r^2+\frac{2}{3}\zeta(3z^2-r^2),$$

or

$$2rq=b^2-\left(1+\frac{4}{3}\zeta\right)r^2+\frac{2}{3}\zeta(3z^2-r^2):$$

and therefore in the prolate spheroid

$$q\times\frac{4\pi}{3}\left\{kr+\frac{(K-k)\,R^3}{r^2}\right\}=\frac{2\pi}{3}\left\{k+\frac{(K-k)\,R^3}{r^3}\right\}\times\left\{b^2-(1+\frac{4}{3}\zeta)\,r^2\right\}+\frac{2\pi}{3}\left\{k+\frac{(K-k)\,R^3}{r^3}\right\}.\frac{2\zeta}{3}.(3z^2-r^2).$$

Spheroidal form found to be possible.

This expression is evidently of the same form as that found above from the condition of equilibrium: and it will exactly coincide with it if the two terms on the right hand side of one are respectively equal to the two terms on the right hand side of the other. The comparison of the first terms gives the value of C; the comparison of the second terms gives the equation

$$\frac{4\pi k}{15}\zeta+\frac{S}{2D^3}=\frac{4\pi}{9}\left\{k+\frac{(K-k)\,R^3}{r^3}\right\}\zeta.$$

From the latter,

$$\frac{S}{2D^3}=\zeta\times\left\{\frac{4\pi k}{9}-\frac{4\pi k}{15}+\frac{4\pi}{9}.\frac{(K-k)\,R^3}{r^3}\right\}=\frac{4\pi}{3}\zeta.\left\{\frac{2k}{15}+\frac{(K-k)\,R^3}{3r^3}\right\}$$

and

$$\zeta=\frac{S}{2D^3}.\frac{1}{\frac{4\pi}{3}.\left\{\frac{2k}{15}+\frac{(K-k)\,R^3}{3r^3}\right\}}.$$

Ellipticity determined

The spheroidal form is therefore a possible form of equilibrium, and the proportion of the axes must be $1:1-\zeta$, where ζ has the value just found.

(41.) The value of q, found above from the properties of the spheroid, is $\frac{\zeta}{3r}(3z^2-r^2)+$ constant; which constant will be found, by the reasoning of (30.), to be $=0$; and therefore $q=\frac{\zeta}{3r}(3z^2-r^2)$. Substituting the value of ζ,

$$q=\frac{S}{2D^3}.\frac{15r^2}{4\pi\{2kr^3+5(K-k)\,R^3\}}.(3z^2-r^2)$$

$$=\frac{15r^4}{4\pi\{2kr^3+5(K-k)\,R^3\}}.\frac{S}{2D^3}.(3\cos^2\theta-1).$$

To reduce this to a form fit for calculation, we may, as before, put $\frac{S}{D^3}=\left(\frac{D_m}{D}\right)^3.\frac{4\pi^2}{T^2}$: to remove K, we must remark that the attraction is nearly the same as if the whole mass were united at the centre of the sphere; but the whole mass (omitting small quantities) is $\frac{4\pi}{3}\left\{(r^3-R^3)\,k+R^3K\right\}$: its attraction on a point at the surface of the water is therefore $\frac{4\pi}{3}\cdot\left\{kr+(K-k)\frac{R^3}{r^2}\right\}$, which (as before) must be made $=g$: therefore $K=\frac{3g}{4\pi\left\{\frac{k}{K}r+\left(1-\frac{k}{K}\right)\frac{R^3}{r^2}\right\}}$, and the expression for q becomes

$$\frac{10\,\pi^2r^2}{T^2g}\cdot\left(\frac{D_m}{D}\right)^3\cdot\frac{\frac{k}{K}r^3+\left(1-\frac{k}{K}\right)R^3}{2\frac{k}{K}r^3+5\left(1-\frac{k}{K}\right)R^3}\,(3\cos^2\theta-1).$$

Expression for elevation in the spheroid.

If the depth of fluid covering the solid nucleus be small, r may be considered $=R$, and then

$$q=\frac{10\,\pi^2r^2}{T^2g}\left(\frac{D_m}{D}\right)^3\;\frac{1}{5-\frac{3k}{K}}\,(3\cos^2\theta-1).$$

(42.) When the density of the fluid is insignificant, $\frac{k}{K}=0$, and the expression for q becomes

$$\frac{2\pi^2r^2}{T^2g}\left(\frac{D_m}{D}\right)^3\cdot(3\cos^2\theta-1)$$

as we have found before. When the density of the fluid is equal to that of the solid nucleus, $\frac{k}{K}=1$, and

$$q=\frac{5\pi^2r^2}{T^2g}\left(\frac{D_m}{D}\right)^3\cdot(3\cos^2\theta-1)$$

or it is equal to the former result $\times\frac{5}{2}$. This remarkable difference is produced entirely by the attraction of the elevated portions of water and the diminution of attraction where the water is depressed. Converted into numbers, this value becomes 0·6775 foot $\times\left(\frac{D_m}{D}\right)^3\cdot(3\cos^2\theta-1)$: and the whole difference between the elevations of high and low water is 2·0325 feet. This result nearly coincides with Newton's, as it ought. The circumstances of the earth and water will be represented most nearly by taking $\frac{k}{K}=\frac{2}{11}$. The same results as to the proportion of the elevations found on different assumptions of the proportion of the densities of earth and water, which we have found for the effect of the sun, apply in all respects to the effect of the moon.

(43.) We shall now consider the effect of the combination of the tides produced by the Sun and the Moon; the place of observation being at any point on the earth's surface, which is supposed to be carried round by the earth's daily rotation, while the form of the water continues the same in respect of the positions of the Sun and Moon; and the positions of the Sun and Moon being any whatever. For simplicity of notation, we shall put S′ for the factor of $\left(\frac{D_m}{D}\right)^3\cdot(3\cos^2\theta-1)$ in the expression for the Solar Tide, and M′ for the factor of $\left(\frac{D'_m}{D'}\right)^3\cdot(3\cos^2\theta'-1)$ in the expression for the Lunar Tide; also we shall put $\frac{P}{P_m}$ for $\frac{D_m}{D}$, and $\frac{P'}{P'_m}$ for $\frac{D'_m}{D'}$, to which they are almost exactly equal.

Combination of Solar and Lunar Tides.

(44.) In figure 1, let p be the pole of the earth, t the place at which the tide is observed, u the point to which the moon is vertical, v the point to which the sun is vertical. Then the elevation of the water at t is

$$M'\left(\frac{P'}{P'_m}\right)^3\cdot(3\cos^2tu-1)+S'\left(\frac{P}{P_m}\right)^3\cdot(3\cos^2tv-1).$$

Draw a meridian pw fixed in space, and draw meridians through t, u, v; let s, m be the celestial right ascensions of the sun and moon, and l the terrestrial longitude of the place, as measured from that fixed meridian; σ, μ the celestial declinations of the sun and moon, and λ the terrestrial latitude of the place. Then $\cos tu=\sin\lambda.\sin\mu+\cos\lambda.\cos\mu.\cos\overline{l-m}$: $\cos tv=\sin\lambda.\sin\sigma+\cos\lambda.\cos\sigma.\cos\overline{l-s}$; and the elevation of the water is

$$M'\left(\frac{P'}{P'_m}\right)^3\cdot\left\{(1-3\sin^2\lambda).\left(\frac{3}{2}\cos^2\mu-1\right)+\frac{3}{2}\sin 2\lambda.\sin 2\mu.\cos\overline{l-m}+\frac{3}{2}\cos^2\lambda.\cos^2\mu.\cos 2.\overline{l-m}\right\}$$

$$+S'\left(\frac{P}{P_m}\right)^3\cdot\left\{(1-3\sin^2\lambda).\left(\frac{3}{2}\cos^2\sigma-1\right)+\frac{3}{2}\sin 2\lambda.\sin 2\sigma.\cos\overline{l-s}+\frac{3}{2}\cos^2\lambda.\cos^2\sigma.\cos 2.\overline{l-s}\right\}$$

of which the different parts may be more advantageously combined in the following form:

$$(1-3\sin^2\lambda).\left\{M'\left(\frac{P'}{P'_m}\right)^3\cdot\left(\frac{3}{2}\cos^2\mu-1\right)+S'\left(\frac{P}{P_m}\right)^3\cdot\left(\frac{3}{2}\cos^2\sigma-1\right)\right\}$$

$$+\frac{3}{2}\sin 2\lambda.\left\{M'\left(\frac{P'}{P'_m}\right)^3\cdot\sin 2\mu.\cos\overline{l-m}+S'\left(\frac{P}{P_m}\right)^3\cdot\sin 2\sigma.\cos\overline{l-s}\right\}$$

$$+\frac{3}{2}\cos^2\lambda.\left\{M'\left(\frac{P'}{P'_m}\right)^3\cdot\cos^2\mu.\cos 2.\overline{l-m}+S'\left(\frac{P}{P_m}\right)^3\cdot\cos^2\sigma.\cos 2.\overline{l-s}\right\}.$$

We shall consider the different terms of this expression in order.

Tides of long period.

(45.) The first line does not depend upon l, m, or s, and is therefore independent of the right ascensions of the sun and moon or the hour of the day. It does not therefore represent a *Tide* in the ordinary sense of the word. Nevertheless it depends upon μ and σ, and therefore will vary with the variation of the declination of the sun and moon. But it is indifferent whether the declination is north or south. As the moon's declination goes through all its changes in respect of magnitude (without regard of sign) in half a lunation, the term depending on M′ will produce a slow tide, going through all its changes in 14 days nearly. There will also be a slow tide produced by the term depending on S′, going through its changes in half a year. These Tides do not exist for any place at which the sine of latitude $=\sqrt{\frac{1}{3}}$: near the equator, the water is high (as depending on this cause) when the moon and sun are in the equator; near the earth's pole, it is low at the same time; the greatest change of surface at the equator, supposing the sine of the greatest declination to be $\frac{2}{5}$, will be $\frac{6}{25}\left\{M'\left(\frac{P'}{P'_m}\right)+S'\left(\frac{P}{P_m}\right)^3\right\}$ nearly; the greatest change at the pole will be $\frac{12}{25}\left\{M'\left(\frac{P'}{P'_m}\right)^3+S'\left(\frac{P}{P_m}\right)^3\right\}$.

Diurnal Tides.

(46.) The second line consists of two parts, each of which is a multiple of the cosine of $\overline{l-m}$ or $\overline{l-s}$. This then represents two tides; of which one goes through all its changes, while the distance of the meridian passing through the place from the meridian passing through the moon (or the moon's hour-angle) changes by 360°; and the other goes through all its changes while the sun's hour-angle changes by 360°. Each of these then produces a *diurnal* tide; and their combined effect will be represented by a single *diurnal* tide of varying extent, and which follows the moon's transit at a variable interval. For, the line may be put in this form:

$$+\frac{3}{2}\sin 2\lambda\left\{M'\left(\frac{P'}{P'_m}\right)^3\sin 2\mu.\cos\overline{l-m}\quad+S'\left(\frac{P}{P_m}\right)^3\sin 2\sigma.\cos(\overline{l-m}+\overline{m-s})\right\}$$

Observing that $\cos(\overline{l-m}+\overline{m-s})=\cos\overline{m-s}.\cos\overline{l-m}-\sin\overline{m-s}.\sin\overline{l-m}$, this may be thus expressed:

$$+\frac{3}{2}\sin 2\lambda\left\{M'\left(\frac{P'}{P'_m}\right)^3\sin 2\mu+S'\left(\frac{P}{P_m}\right)^3\cdot\sin 2\sigma.\cos\overline{m-s}\right\}\cos\overline{l-m}$$

$$-\frac{3}{2}\sin 2\lambda.S'\left(\frac{P}{P_m}\right)^3\cdot\sin 2\sigma.\sin\overline{m-s}.\sin\overline{l-m}.$$

Remarking that $A.\cos\overline{l-m}-B\sin\overline{l-m}=\sqrt{A^2+B^2}\left\{\frac{A}{\sqrt{A^2+B^2}}\cos\overline{l-m}-\frac{B}{\sqrt{A^2+B^2}}\sin\overline{l-m}\right)\right\}$

$$=\sqrt{A^2+B^2}\left\{\cos E.\cos\overline{l-m}-\sin E.\sin\overline{l-m}\right\},\text{ where }\tan E=\frac{B}{A};$$

$$=\sqrt{A^2+B^2}.\cos\overline{l-m+E};$$

this may be put in the following form:

$$+\frac{3}{2}\sin 2\lambda\sqrt{\left\{M'^2\left(\frac{P'}{P'_m}\right)^6\cdot\sin^2 2\mu+2M'S'\left(\frac{P'P}{P'_mP_m}\right)^3\sin 2\mu.\sin 2\sigma.\cos\overline{m-s}+S'^2\left(\frac{P}{P_m}\right)^6\sin^2 2\sigma\right\}}\times\cos\overline{l-m+E}$$

where

$$\tan E = \frac{S'\left(\frac{P}{P_m}\right)^3 . \sin 2\sigma . \sin \overline{m-s}}{M'\left(\frac{P'}{P'_m}\right)^3 \sin 2\mu + S'\left(\frac{P}{P_m}\right)^3 \sin 2\sigma . \cos \overline{m-s}}.$$

On this diurnal tide we may make the following remarks.

(47.) 1st. It is 0 at the equator (where $\lambda = 0$), and at the pole (where $\lambda = 90°$), and greatest for places at latitude 45°. For these the greatest value (which occurs when $m-s=0$, or at new moon) is

$$+\frac{3}{2}\left\{M'\left(\frac{P'}{P'_m}\right)^3 \sin 2\mu' + S\left(\frac{P}{P_m}\right)^3 \sin 2\sigma\right\} \cos \overline{l-m}:$$

and as the greatest value of $\sin 2\mu$ and $\sin 2\sigma$ will be about $\frac{3}{4}$, the greatest diurnal tide will be about $\frac{9}{8}\left\{M'\left(\frac{P'}{P'_m}\right)^3 + S'\left(\frac{P}{P_m}\right)^3\right\} \cos \overline{l-m}$: and the greatest oscillation produced by the diurnal tide will be $\frac{9}{4}\left\{M'\left(\frac{P'}{P'_m}\right)^3 + S'\left(\frac{P}{P_m}\right)^3\right\}$.

Changes in the diurnal Tide.

(48.) 2d. The position of the meridian passing through the place of observation, with reference to the position of the meridian passing through the place of the moon, at the time of high water as produced by the diurnal tide, is determined by the equation $l-m+E=0$, or $m-l=+E$. This is the moon's hour-angle to the east of the meridian at the time of high diurnal tide. If now we examine the expression for $\tan E$, we find that E undergoes the following changes. If $\sin \overline{m-s}$ is positive, and μ and σ are both positive, E is a positive angle and not very great, since $\frac{S'}{M'}$ is a fraction, as will be inferred from the remark on the relative influence of the sun and moon in (15.) But if, while σ retains the same sign, μ changes its sign (in consequence of the moon crossing the equator), the denominator will successively become small, 0, and negative. E therefore increases suddenly to 90°, and to an angle not much less than 180°. This change of angle shows that the phænomena of this Tide are very rapidly reversed when the moon crosses the equator: that, instead of its high water occurring when the moon is a little way east of the upper meridian, it occurs when the moon is a little way east of the lower meridian. At the time of the moon's crossing the equator the tide will be small: for it will depend on S′ only. This supposes that $\sin \overline{m-s}$ has not changed sign; if it diminishes to 0 and then becomes negative, $\tan E$ gradually becomes a smaller negative quantity and then becomes positive, or E exceeds 180°; and the high water takes place when the moon is west of the lower meridian. The reader can easily examine the changes which occur in other positions of the two luminaries; but the following rules will be found to comprehend nearly the whole.

Rule for the time of diurnal high water.

If we consider the sidereal *day* to be defined as the time between the first point of Aries passing the meridian and the first point of Libra passing the meridian; and the sidereal *night* to be the time between the passages of the first point of Libra and of the first point of Aries; and suppose the latitude of the place of observation to be north; then the high water produced by diurnal tide always occurs *in* the sidereal day, if we neglect the sun's action, or *in or near* the sidereal day if the sun's action be small; and its time is that of the moon's passage over the upper or lower meridian (according as her longitude is less or greater than 180°) *exactly* if the sun's action be neglected, or *nearly* if the sun's action be small. The sidereal time of the high tide is later and later each successive day; the magnitude of the tide is greatest when the high tide occurs nearly at the middle of the sidereal day; and when the sudden shift takes place from the end of sidereal day to the beginning of sidereal day, the diurnal tide is extremely small.

Semidiurnal Tide.

(49.) We shall now consider the third line of the expression in (44.). It consists of two parts, each of which goes through its changes twice, while $l-m$ for one, or $l-s$ for the other, increases by 360°. Each of these, therefore, produces a semidiurnal tide (the term semidiurnal being, for one, referred to the length of the lunar day, and, for the other, being referred to the length of the solar day). These two tides may be compounded into one semidiurnal tide, by the same process as that in (46.); and the expression for the elevation of the water from this cause becomes

$$+\frac{3}{2}\cos^2 \cdot \sqrt{\left\{M'^2\left(\frac{P'}{P'_m}\right)^6 \cos^4\mu + 2M'S'\left(\frac{P'P}{P'_m P_m}\right)^3 \cos^2\mu . \cos^2\sigma . \cos 2.\overline{m-s} + S'^2\left(\frac{P}{P_m}\right)^6 \cos^4\sigma\right\}} \times \cos \overline{2(l-m)+F}$$

where

$$\tan F = \frac{S'\left(\frac{P}{P_m}\right)^3 \cos^2\sigma . \sin 2.\overline{m-s}}{M'\left(\frac{P'}{P'_m}\right)^3 \cos^2\mu + S'\left(\frac{P}{P_m}\right)^3 \cos^2\sigma . \cos 2.\overline{m-s}}.$$

We shall proceed to discuss several cases of this formula.

(50.) 1st. The coefficient is greatest for places at the equator, and is 0 at the poles; for all parts of the earth, therefore, it may be considered to have a sensible value. In the succeeding statements of value we shall express the values corresponding to the equator: those for other points will be found by multiplying by $\cos^2\lambda$.

Spring Tides.

(51.) 2nd. Suppose that $m-s$ is 0° or 180° (that is, that it is new moon or full moon): the expression becomes

$$\frac{3}{2}\left\{M'\left(\frac{P'}{P'_m}\right)^3\cos^2\mu+S'\left(\frac{P}{P_m}\right)^3\cos^2\sigma\right\}\times\cos 2.\overline{l-m}.$$

The extent of oscillation of the surface of the water will here be

$$3\left\{M'\left(\frac{P'}{P'_m}\right)^3\cos^2\mu+S'\left(\frac{P}{P_m}\right)^3\cos^2\sigma\right\}.$$

The value of $\cos\sigma$ will not much differ from that of $\cos\mu$; therefore the expression will be nearly

$$3\cos^2\mu\left\{M'\left(\frac{P'}{P'_m}\right)^3+S'\left(\frac{P}{P_m}\right)^3\right\}.$$

This will be greatest, *cæteris paribus*, when $\cos\mu=1$, that is, for new or full moon, when the sun is at either equinox. For a solstitial new or full moon, $\cos^2\mu=\frac{21}{25}$ nearly, and the expression is

$$3.\frac{21}{25}\left\{M'\left(\frac{P'}{P'_m}\right)^3+S'\left(\frac{P}{P_m}\right)^3\right\}.$$

Neap Tides.

(52.) 3rd. Suppose that $\overline{m-s}$ is 90° or 270° (that is, that the moon is in quadratures): the expression becomes

$$\frac{3}{2}\left\{M'\left(\frac{P'}{P'_m}\right)^3\cos^2\mu-S'\left(\frac{P}{P_m}\right)^3\cos^2\sigma\right\}\times\cos 2.\overline{l-m};$$

and the whole extent of oscillation is

$$3\left\{M'\left(\frac{P'}{P'_m}\right)^3\cos^2\mu-S'\left(\frac{P}{P_m}\right)^3\cos^2\sigma\right\}.$$

If the sun is at either equinox, the moon will be at solstice, and the whole extent of oscillation is nearly $3\left\{M'\left(\frac{P'}{P'_m}\right)^3.\frac{21}{25}-S'\left(\frac{P}{P_m}\right)^3\right\}$. If the sun is at either solstice, the moon will be at equinox, and the whole extent of oscillation is $3\left\{M'\left(\frac{P'}{P'_m}\right)^3-S'\left(\frac{P}{P_m}\right)^3.\frac{21}{25}\right\}$. Combining these remarks with those of the last paragraph, we find that the syzygial tides are greatest, and the quadratural tides are least, at the equinoxes, and that these are respectively the greatest and least of all the tides.

(53.) 4th. If we put $M'+N$ for $M'\left(\frac{P'}{P'_m}\right)^3\cos^2\mu$, and $S'+T$ for $S'\left(\frac{P}{P_m}\right)^3\cos^2\sigma$, and consider that, in consequence of the small variation of the factors $\left(\frac{P'}{P'_m}\right)^3\cos^2\mu$ &c., N and T will be small, and their powers above the first may therefore be neglected without great error, the whole extent of oscillation is expressed by

$$3\sqrt{\left\{M'^2+2M'S'\cos 2.\overline{m-s}+S'^2+(2M'+2S'\cos 2.\overline{m-s})N+(2S'+2M'\cos 2.\overline{m-s})T\right\}}$$

$$=3\sqrt{\left\{M'^2+2M'S'\cos 2.\overline{m-s}+S'^2\right\}}+3\frac{M'+S'\cos 2.\overline{m-s}}{\sqrt{\{M'^2+2M'S'\cos 2.\overline{m-s}+S'^2\}}}N+3\frac{S'+M'\cos 2.\overline{m-s}}{\sqrt{\{M'^2+2M'S'\cos 2.\overline{m-s}+S'^2}}T.$$

If $P'=P'_m+p'=P'_m\left(1+\frac{p'}{P'_m}\right)$, then $\left(\frac{P'}{P'_m}\right)^3\cos^2\mu=1+3\frac{p'}{P'_m}-\sin^2\mu$ nearly; and if $P=P_m+p$, then $\left(\frac{P}{P_m}\right)^3\cos^2\sigma=1+\frac{3p}{P_m}-\sin^2\sigma$ nearly. Consequently $N=\frac{3M'p'}{P'_m}-M'\sin^2\mu$, and $T=\frac{3S'p}{P_m}-S'\sin^2\sigma$. Substituting these in the last formula, we find the following approximate expression for the whole extent of oscillation:

Approximate expression for the oscillation of the

$$3\sqrt{\left\{M'^2+2M'S'\cos 2.\overline{m-s}+S'^2\right\}}$$

$$+9\frac{M'^2+M'S'\cos 2.\overline{m-s}}{P'_m\sqrt{\{M'^2+2M'S'\cos 2.\overline{m-s}+S'^2\}}}p'$$

water produced by semidiurnal Tide.

$$-3\frac{M'^2+M'S'\cos 2.\overline{m-s}}{\sqrt{\{M'^2+2M'S'\cos 2.\overline{m-s}+S'^2\}}}\sin^2\mu$$

$$+9\frac{S'^2+M'S'\cos 2.\overline{m-s}}{P_m\sqrt{\{M'^2+2M'S'\cos 2.\overline{m-s}+S'^2\}}}p$$

$$-3\frac{S'^2+M'S'\cos 2.\overline{m-s}}{\sqrt{\{M'^2+2M'S'\cos 2.\overline{m-s}+S'^2\}}}\sin^2\sigma.$$

This form is convenient for calculation. For the first or principal term depends upon no variable except $\overline{m-s}$, the angle by which the moon's right ascension exceeds the sun's right ascension, and may therefore be expanded in a single table to any extent: the other terms depend each upon two variable quantities (of which one is $\overline{m-s}$, and the other is the difference of parallax from the mean, or the declination), and will therefore be contained each in a table of double entry, which, however, needs not to be extensive. It is nearly in this form that the tables have been constructed which have lately been used for the prediction of tides.

Retard of high water upon the moon's transit.

(54.) 5th. The time of high water is determined by making $2(l-m)+F=0$, or $l-m=-\frac{F}{2}$. Now $l-m$ is evidently the angle by which the place of observation has travelled to the east of the meridian passing through the moon, or it is the time (expressed as an hour-angle) by which the moon has apparently passed the meridian of the place. Remarking now that the difference between F and tan F is so small (for these investigations) that we may use one for the other, and also that, as tan F or F is expressed in parts of radius, it must, in order to give an expression in minutes of time, be multiplied by $\frac{24\times 60}{2\pi}$, we find for the retardation of high water after the moon's passage over the meridian, expressed in minutes of time,

$$-\frac{24\times 60}{4\pi}\times\frac{(S'+T).\sin 2.\overline{m-s}}{M'+N+(S'+T)\cos 2.\overline{m-s}}.$$

These minutes, it is to be remarked, are strictly minutes of *lunar* time (that is, of time in which the measure of 24 hours is the interval between two transits of the moon): but they will not sensibly differ from solar minutes. Expanding to the first power of N and T, the retardation is

$$-\frac{360^m}{\pi}\times\left\{\frac{S'\sin 2.\overline{m-s}}{M'+S'\cos 2.\overline{m-s}}-\frac{S'\sin 2.\overline{m-s}}{(M'+S'\cos 2.\overline{m-s})^2}N+\frac{M'\sin 2.\overline{m-s}}{(M'+S'\cos 2.\overline{m-s})^2}T\right\};$$

Approximate expression for the retardation.

which, as before, will be conveniently expressed for calculation in the following form:

$$-\frac{360^m}{\pi}.\frac{S'\sin 2.\overline{m-s}}{M'+S'\cos 2.\overline{m-s}}$$

$$+\frac{1080^m}{\pi}.\frac{M'S'.\sin 2.\overline{m-s}}{P'_m(M'+S'\cos 2.\overline{m-s})^2}p'$$

$$-\frac{360^m}{\pi}.\frac{M'S'.\sin 2.\overline{m-s}}{(M'+S'.\cos 2.\overline{m-s})^2}\sin^2\mu$$

$$-\frac{1080^m}{\pi}.\frac{M'S'.\sin 2.\overline{m-s}}{P_m(M'+S'\cos 2.\overline{m-s})^2}p$$

$$+\frac{360^m}{\pi}.\frac{M'S'.\sin 2.\overline{m-s}}{(M'+S'.\cos 2.\overline{m-s})^2}\sin^2\sigma.$$

Principal changes in the retardation.

(55.) The changes in the value of this expression which are most interesting to the general reader are principally those of the first term. It appears that when $\overline{m-s}$ is greater than 0° and less than 90°, or greater than 180° and less than 270°, this term is negative; that is, high water should precede the moon's transit while the moon is passing from syzygy to quadrature. While the moon is passing from quadrature to syzygy, high water should follow the moon's transit. The greatest value of this acceleration or retard for the mean values M′ and S′ will be found by differentiating the first term with respect to $\overline{m-s}$, and making the differential coefficient $=0$: this gives $\cos 2.\overline{m-s}=-\frac{S'}{M'}$, from which tan F at its maximum value $=\pm\frac{S'}{\sqrt{(M'^2-S'^2)}}$, and

Expression for greatest retard.

$\sin F = \pm \frac{S'}{M'}$. This expression is useful, because, in a long series of observations, it is possible to determine the value of F with considerable accuracy, and that determination will immediately give us the value of the fraction $\frac{S'}{M'}$, or the proportion of the Sun's mean force to the Moon's mean force.

Expressions referred to mean declination.

(56.) In the expressions for N and T, we have proceeded on the supposition, that it is most convenient to refer the actual values of $M'\left(\frac{P'}{P'_m}\right)^3 \cos^2\mu$ and $S'\left(\frac{P}{P_m}\right)^3 \cos^2\sigma$ to the values which they would have, if the respective parallaxes had their mean values, and if the declinations were 0. With regard to the parallaxes, there is no need for alteration; but with regard to the declinations, it has sometimes been found more convenient to refer to a declination Δ, which gives for $\cos^2\Delta$ a value that is nearly a mean among all the values of $\cos^2\mu$ or $\cos^2\sigma$ (conditions that are sensibly equivalent) which occur in observation. This gives for Δ a value of 16° 35′ nearly. Then the term $M'\left(\frac{P'}{P'_m}\right)^3 \cos^2\mu$ must be expressed in the form $M'\left(\frac{P'}{P'_m}\right)^3 . (\cos^2\Delta + \overline{\cos^2\mu - \cos^2\Delta})$ or $M' \cos^2\Delta \left\{1 + \frac{3p'}{P'_m} + \frac{\cos^2\mu - \cos^2\Delta}{\cos^2\Delta}\right\}$. If we put M_Δ for $M' \cos^2\Delta$, and call the last expression $M_\Delta + N$, we obtain $N = \frac{3M_\Delta p'}{P'_m} - M_\Delta \frac{\sin^2\mu - \sin^2\Delta}{\cos^2\Delta}$. A similar change must be made in the value of T. And thus it appears, that the expressions of (53.) and (54.) may still be retained, provided that we put M_Δ and S_Δ instead of M' and S', and that instead of $\sin^2\mu$ and $\sin^2\sigma$ we put $\frac{\sin^2\mu - \sin^2\Delta}{\cos^2\Delta}$ and $\frac{\sin^2\sigma - \sin^2\Delta}{\cos^2\Delta}$. Then the greatest value of F which we have spoken of in (55.) will be the mean of all the greatest values of acceleration or retard produced in a very long series of observations; since then, not only will the positive and negative values of p' and p, (the excesses and defects of actual parallax as referred to mean parallax,) destroy each other, but also the positive and negative values of $\sin^2\mu - \sin^2\Delta$ and $\sin^2\sigma - \sin^2\Delta$, (the excesses and defects of the actual values of $\sin^2\mu$ and $\sin^2\sigma$, as referred to their mean values,) will destroy each other; and thus a value of F will be obtained, from which $\frac{S_\Delta}{M_\Delta}$ or its equal $\frac{S'}{M'}$ can immediately be found.

(57.) With regard to the three principal parts into which we have resolved the lunisolar tide, we may make the following remarks:—

The first part treated in (45.) &c., is so slow in its period that it will generally be lost among the others whose recurrence is so much more frequent. If, however, we wished to examine its law, we should remark, that its variations depend chiefly on the variations of $\sin^2\mu$ and $\sin^2\sigma$. And we see that $\sin^2\mu$ will be (for a few lunations) nearly proportional to the square of the sine of the moon's longitude from a given point, and therefore nearly proportional to the square of the sine of an angle increasing proportionally to the time (which we will call $At + B$, putting t for the time), or that $\sin^2\mu \propto \sin^2(At + B) \propto \frac{1}{2} - \frac{1}{2}\cos(2At + 2B)$. From this it appears that the fluctuation of the surface of the water, dependent on this cause, would be expressed (omitting the constant terms) by a multiple of $\cos(2At + 2B)$. In like manner the fluctuation depending on $\cos^2\sigma$ would be expressed by $\cos(2Ct + 2D)$.

(58.) The fluctuations depending on the second and third parts, treated of from (46.) to (53.) are, as we have seen, expressed by cosines of multiples of $l - m$ and $l - s$, which for a few tides can be expressed nearly enough by cosines of multiples of $l - m$. This angle is nearly proportional to the time, and thus these fluctuations can be expressed in the same form as those above.

(59.) If we considered the variations which the factors of these different terms undergo, arising from the change of parallax, declination, &c., it would be found that they would all be expressed by series of cosines of multiples of the time; which combined as factors with the cosines of the former would produce cosines of new multiples of the time.

All the fluctuations may be expressed by cosines.

(60.) Thus it appears that the fluctuation of the water will be expressed by a multitude of terms, each of which will be of the form $C \cos(2At + 2B)$. If any one of these terms existed alone, the following curious law would be true. Suppose the lines of the extreme elevation and extreme depression of the surface of the water to be marked upon a wharf-wall; and suppose a circle to be described upon the wall, touching those two lines; then if the circumference of that circle be divided into equal parts, the fall of the water will expose the successive equal parts in successive equal times. For, since the whole fluctuation is 2C, C is the radius of our circle; and the elevation of any point of the circumference above the mean (or above the centre of the circle) is $C \times$ cosine angle from the top; but the tidal term gives for that elevation $C \times$ cosine $(2At + 2B)$, and therefore $2At + 2B$ must be the same thing as that angle from the top; and, therefore, that angle, and the circumference which is proportional to it, must have increased proportionally to the time. But this law does not hold for an assemblage of a multitude of such terms.

(61.) We have now given a tolerably complete investigation of the equilibrium-theory. But before quitting this section we will point out roughly how far it agrees with observation.

(62.) The most conspicuous tide, on the coasts of Europe at least, is the semidiurnal. The acceleration or retard of this tide on the moon's transit, does not at one port in a hundred agree in any measure with the result of this theory. The extreme differences of acceleration or retard (F of article 55., &c.) agree better, but are not exactly the same at all ports. They do not occur on the days on which this theory predicts them, but always later. The absolute elevation of the tide is great at one port and small at another, without any relation to the quantity calculated from the theory. The proportions of the elevations however at the same port, in different stages of the lunation, agree pretty well with the theory (though not equally at all ports); yet the critical phænomena (spring and neap tides) occur later than the theory gives them, and that by a quantity which is not the same as the delay of extreme values of F, mentioned above. The peculiar phænomena of river tides are not touched by this theory.

(63.) The diurnal tide ought to be discovered, in observation, in one of the following ways. If the diurnal tide were much greater than the semidiurnal, there would appear, to common observation, to be only one tide in the day with some irregularities. If it were much smaller, its effect would be shown in either or both the following ways. If its high water occurred nearly at one high water of semidiurnal tide, its low water would occur nearly at another high water of semidiurnal tide; and one of the semidiurnal tides would be increased and the other would be diminished. If its high water occurred between two semidiurnal high waters, then at the first semidiurnal high water the surface would still be rising in consequence of diurnal tide, and the compound high water would be later; and at the second semidiurnal high water the surface would be falling in consequence of diurnal tide, and the compound high water would therefore be past; consequently the interval between these two high waters would be less than it ought to be on the usual laws of semidiurnal tide. The diurnal tide ought, in these latitudes, to be equal or nearly equal to the semidiurnal tide. Yet in the Thames it is absolutely insensible; and in other parts, as well of England as of other parts of Europe and America, though discoverable, it is not notorious, and has only been found from the observations made by men of science. It has been found to be very conspicuous at some places near the equator and some places near the pole, where it ought not to be discoverable or scarcely discoverable.

The Tides of longer period have scarcely been observed.

(64.) Combining these remarks with those which we made at the introduction of this theory (14.), it must be allowed that it is one of the most contemptible theories that was ever applied to explain a collection of important physical facts. It is entirely false in its principles, and entirely inapplicable in its results. Yet, strange as it may appear, this theory has been of very great use. It has served to show that there are forces in nature following laws which bear a not very distant relation to some of the most conspicuous phænomena of the Tides; and, what is far more important, it has given an algebraic form to its own results, divided into separate parts analogous to the parts into which the tidal phænomena may be divided, admitting easily of calculation and of alteration, and thus at once suggesting the mode of separating the tidal movements, and affording numerical results of theory with which they are to be compared. The greatest mathematicians and the most laborious observers of the present age have agreed equally in rejecting the *foundation* of this theory and comparing all their observations with its *results*. And, till theories are perfect (a thing scarcely to be hoped for in any subject, and less in the Tides than in any other), this is one of the most important uses of theory.

SECTION III.—LAPLACE'S THEORY OF TIDES.

Laplace's theory is a theory of motion.

(65.) In the theory which we are now about to describe, a prodigious step was made towards a rational explanation, on mathematical principles, of the tidal phænomena. The idea of a state of equilibrium was entirely laid aside, and the motion of the water was legitimately investigated, on the supposition that it is in motion, and subject to all the laws of fluids in motion. It was found necessary, however, in order to make the application of mathematics practicable, to start with two suppositions, which are inapplicable to the state of the earth. These are: that the earth is covered with water; and that the depth of this water is the same through the whole extent of any parallel of latitude. Under these suppositions it is evident that the theory is far from being one of practical application; though it clearly approaches much nearer to truth than the theory of equilibrium which we have already described.

Suppositions by which it is limited.

(66.) It would be useless to offer this theory in the same shape in which Laplace has given it; for the part of the *Mécanique Céleste*, which contains the Theory of Tides, is perhaps on the whole more obscure than any other part of the same extent in that work. We shall give the theory in a form equivalent to Laplace's, and, indeed, so nearly related to it, that a person familiar with the latter will perceive the parallelism of the successive steps. The results at which we shall arrive are the same as those of Laplace.

(67.) We shall commence with a few considerations of a general nature, based upon the suppositions that we have already enunciated, and the additional supposition that the depth of the sea is small compared with the radius of the earth; and taking for granted a knowledge of the principal results of the equilibrium theory.

(68.) The motion of the water which forms the variable elevations of the Tides at different parts of the earth must be conceived to be principally a horizontal oscillation, the water on both sides of the highest point at any time having run towards that point in order to raise the surface there, and, consequently, (as the highest point occupies different positions at different times,) the water at any particular place running sometimes in one direction and sometimes in another. Combining this with the general result of the equilibrium-theory as to semidiurnal Tides, (namely, that the water is equally raised at two opposite points,) it will easily be seen that, if a canal were traced through the water, forming a great circle of the earth, it would (in certain positions at least of the sun and moon) be divided into four parts, in two of which the water is running in one direction, and in the other two it is running in the opposite direction. Suppose that in one of these parts

A small vertical motion of the water implies a large horizontal motion.

the length is 1000 times as great as the depth, and suppose that the water is depressed one foot through its whole extent. It is evident that the volume of the water (omitting the factor depending on the breadth of the canal), for which a new place is to be found, is = the length of the canal × 1 foot, which = 1000 × depth of the canal × 1 foot, or = depth of the canal × 1000 feet. Consequently the water at one end of the canal, if that at the other end remained unmoved in horizontal place, must have moved 1000 feet, or 1000 times as far as the whole vertical motion of any part. The whole of the extraneous *vertical* forces then which act upon the particles of the water may be omitted in our investigations. For these forces are of two kinds. One is that which depends upon the acceleration or retardation of the particles of water in their upward or downward direction: thus, if the water has been raised 1 foot in 6 hours, the force of which we speak is the pressure which must have acted, in order, by its action continued for 6 hours, to produce a motion of 1 foot. It is clear that this is insignificant in comparison with that force which in the same time has produced a motion of 1000 feet. The force of the other kind is the disturbing force of the sun or moon: now the pressure which this causes among the particles of the water depends not only upon the magnitude of the force, but also upon the depth of the column or the length of the canal through which it acts: and, therefore, though its resolved vertical part may be as great as its resolved horizontal part, yet as the vertical part acts only upon a column of water 5 or 6 miles deep (at the utmost), and the horizontal part acts along the whole length of a canal 5000 or 6000 miles long, the pressure among the particles of water which is caused by the former will be insignificant in comparison with that caused by the latter. As regards both these kinds of force then, the vertical force may be put out of consideration. But the same remark does not apply to the vertical force of gravity, nor to the difference in the pressure which it produces, depending on the small tidal difference of elevation of the water at different places. For the force of gravity, as we have seen in (16.), is nearly forty millions of times as great as the sun's disturbing force, and therefore the force of gravity acting on one foot of additional elevation of water would cause as great an additional pressure among the particles of water as the sun's disturbing force acting along a canal whose length is 8000 miles.

Extraneous vertical forces, and forces depending on vertical motion, may be omitted.

Vertical force of gravity on the small elevations of water must not be omitted.

(69.) From this we gather that the only forces which we shall have to consider are: the vertical force of gravity, the resolved disturbing forces of the sun and moon in the horizontal direction at each place, and the forces arising from the horizontal accelerations or retardations of the water in each place. We shall suppose the density of the water insignificant, and gravity therefore will depend simply upon the attraction of the solid earth, and the centrifugal force arising from the earth's rotation.

(70.) Now as the depth of the water is very small compared with the radius of the earth, the horizontal disturbing force will be very nearly the same at the bottom of the water as at the top. Consequently we may conceive the whole motion of the water to be of such a kind that particles which were originally in a vertical line remain in a vertical line, although that vertical line may have had a motion on the earth's surface. The elevation of the water must be supposed to be produced merely by the approach of different vertical lines, (arising from their difference of horizontal velocities,) and the consequent forcing up of the water between them: the depression, by their separation, and the consequent drop of the water to fill up the space between them. The reader will remark, that this is not the most general supposition that we can make in regard to the motion of water, but it is one which is possible, and which is sufficient for our theory. Algebraically speaking, it is not our object to obtain a *general solution* of the equations applying to fluids, but a *particular integral* adapted to the case under consideration.

Partic origin in a ve line n suppo be al in a v line.

(71.) We shall now proceed to put the theory into a mathematical form. In figure 2, let P be the pole of the earth, PA a meridian fixed in space, PS a meridian fixed upon the earth's surface, and therefore travelling away from PA with a uniform angular velocity which we will call n; so that, at the end of the time t, PS will make with PA the angle nt: PT the meridian passing through the original place T of any point of the water whose motion is required. We shall suppose that in the quiescent state of the water the angle SPT would have been ϖ, but that in consequence of the tidal disturbance the particle of water is moved to T′, and the angle ϖ is altered by the variable angle v, so that SPT′ $= \varpi + v$, and APT′ $= nt + \varpi + v$. We shall conceive that the original polar distance of the water at T was θ; but that in consequence of the tidal disturbance it is now $\theta + u$. Also we shall put γ for the depth of the water at T, supposed quiescent, and w for its tidal elevation above the quiescent state when at T′. Here γ, in conformity with the supposition made in (65.), is to be considered a function of θ only: u, v, and w are all to be considered as functions of θ, ϖ, and t.

Investigation of the equation of continuity.

(72.) The equation which we shall first form is that which expresses that, however any part of the fluid is transported by the tidal and rotatory motions, it occupies still the same volume. Take another point U′ corresponding to another particle of water U, which was originally on the same meridian with T, and whose polar distance was originally $\theta+\delta\theta$, and therefore is now $\theta+u+\left(1+\frac{du}{d\theta}\right)\delta\theta$ nearly. The angle APU′ has the value which $nt+\varpi+v$ receives when $\theta+\delta\theta$ is used instead of θ in forming the value of v: it is therefore $nt+\varpi+v+\left(\frac{dv}{d\theta}\right)\delta\theta$ nearly. Also take two points, V′ and W′, corresponding to two points V and W, whose polar distances were originally θ, and $\theta+\delta\theta$, but which were upon a meridian making with PS the angle $\varpi+\delta\varpi$. The polar distances of these two points have now respectively the values $\theta+u+\frac{du}{d\varpi}\delta\varpi$ and $\theta+u+\left(1+\frac{du}{d\theta}\right)\delta\theta+\frac{du}{d\varpi}\delta\varpi$, and their angular distances from PA have respectively the values $nt+\varpi+v+\left(1+\frac{dv}{d\varpi}\right)\delta\varpi$ and $nt+\varpi+v+\left(1+\frac{dv}{d\varpi}\right)\delta\varpi+\frac{dv}{d\theta}\delta\theta$. The distance, therefore, from T′ to U′ (if r be the radius of the spherical or spheroidal surface of the water) is sensibly equal to $r\left(1+\frac{du}{d\theta}\right)\delta\theta$, and that from V′ to W′ is the same. Also the difference of angular distances from PA, between T′ and V′, is sensibly equal to $r\left(1+\frac{dv}{d\varpi}\right)\delta\varpi$, and that between U′ and W′ is sensibly the same. Now the area of the surface upon which the water originally stood is seen without difficulty to be $r\delta\theta\times r\sin\left(\theta+\frac{\delta\theta}{2}\right).\delta\varpi$: and, therefore, its original volume

$$=r\delta\theta\times r\sin\left(\theta+\frac{\delta\theta}{2}\right).\delta\varpi\times\gamma.$$

The area upon which it now stands is not estimated so readily, because its sides are inclined; namely, one pair making with the meridian the small angle $\frac{1}{r\delta\theta}\times r.\sin\theta.\frac{dv}{d\theta}\delta\theta=\sin\theta.\frac{dv}{d\theta}$, and the other pair making with the parallel the small angle $\frac{1}{r\sin\theta\delta\varpi}\times r\frac{du}{d\varpi}\delta\varpi=\frac{1}{\sin\theta}.\frac{du}{d\varpi}$. These small inclinations do not, however, produce any sensible effect on the area. The reader will perceive this most readily by estimating the area of a parallelogram *abed*, figure 3, whose sides are inclined to the sides of the rectangle *acgf*. For the area of *abed*

$$\begin{aligned}&=ab\times ad\times\sin bad=ab\times ad\times\sin(90^\circ-bac-daf)=ab\times ad\times\cos(bac+daf)\\&=ab\times ad\times(\cos bac.\cos daf-\sin bac.\sin daf)\\&=(ab.\cos bac)\times(ad.\cos daf)\times(1-\tan bac.\tan daf\\&=ac.af.(1-\tan bac.\tan daf),\end{aligned}$$

which it is evident differs from $ac.af$ only by the product of $ac.af$ into a small quantity of the second order. In like manner we may estimate the area T′U′W′V′ without regard to the inclination of its sides; and it becomes, therefore,

$$r\left(1+\frac{du}{d\theta}\right)\delta\theta\times r\sin\left\{\theta+u+\left(1+\frac{du}{d\theta}\right)\frac{\delta\theta}{2}\right\}\times\left(1+\frac{dv}{d\varpi}\right)\delta\varpi.$$

The depth of the water, which at the original place was γ, is now altered, from two causes: first, because $\theta+u$, upon which it depends, differs from θ; and, secondly, because there is the tidal elevation of the surface; it is, therefore, $\gamma+\frac{d\gamma}{d\theta}u+w$. The volume of the water standing upon T′V′W′U′ is, therefore,

$$r\left(1+\frac{du}{d\theta}\right)\delta\theta\times r\sin\left\{\theta+u+\left(1+\frac{du}{d\theta}\right)\frac{\delta\theta}{2}\right\}\times\left(1+\frac{dv}{d\varpi}\right)\delta\varpi\times\left(\gamma+\frac{d\gamma}{d\theta}u+w\right)$$

$$=r\delta\theta\times r\sin\left(\theta+\frac{\delta\theta}{2}\right).\delta\varpi\times\gamma\times\left(1+\frac{du}{d\theta}\right)\times\left\{1+\text{cotan}\,\overline{\theta+\frac{\delta\theta}{2}}.\overline{u+\frac{du}{d\theta}.\frac{\delta\theta}{2}}\right\}\times\left(1+\frac{dv}{d\varpi}\right)\times\left(1+\frac{u}{\gamma}.\frac{d\gamma}{d\theta}+\frac{w}{\gamma}\right).$$

Making this equal to the original volume, or

$$r\delta\theta\times r\sin\left(\theta+\frac{\delta\theta}{2}\right)\delta\varpi\times\gamma,$$

we have

$$1=\left(1+\frac{du}{d\theta}\right)\times\left\{1+\text{cotan}\,\overline{\theta+\frac{\delta\theta}{2}}.\overline{u+\frac{du}{d\theta}.\frac{\delta\theta}{2}}\right\}\times\left(1+\frac{dv}{d\varpi}\right)\times\left(1+\frac{u}{\gamma}.\frac{d\gamma}{\delta\theta}+\frac{w}{\gamma}\right);$$

or, multiplying out these quantities, rejecting products of the small terms, and rejecting the insignificant terms depending on $\delta\theta$,

$$0=\frac{du}{d\theta}+u\,\text{cotan}\,\theta+\frac{dv}{d\varpi}+\frac{u}{\gamma}.\frac{d\gamma}{d\theta}+\frac{w}{\gamma}.$$

If we multiply this by γ, it becomes

$$0=\frac{d}{d\theta}(u\gamma)+u\gamma.\text{cotan}\,\theta+\gamma\frac{dv}{d\varpi}+w;$$

and if we multiply again by $\sin\theta$, it becomes

$$0=\frac{d}{d\theta}(u\gamma\sin\theta)+\gamma\sin\theta.\frac{dv}{d\varpi}+w.\sin\theta.$$

This is the equation expressing that the same water always occupies the same volume: it is frequently called the *equation of continuity*.

Explanation of the pressure of fluids.

(73.) We now proceed to investigate the equations applying strictly to the *motion* of the water. We will first allude in a few words to the general equations of motion of incompressible fluids, referring to our article HYDRODYNAMICS, page 276, or to other treatises, for a more detailed exposition. Let the places of the particles of a fluid at any instant of time be defined by three rectangular coordinates: suppose x, y, z, to be the coordinates of one point, and p the pressure among the particles at that point. The pressure may perhaps be most easily conceived in the following manner:—Suppose a plane to be inserted in the fluid, and suppose the fluid on one side of the plane to be removed; it will be necessary to apply a pressure to this plane, in order to maintain the remaining fluid in the same state (whether of repose, or of motion or change of motion); and the pressure for every square unit of surface on this plane is our quantity p. This pressure ought in strictness to be estimated as a statical pressure by the number of pounds and ounces under the action of gravity, at a given place on the earth's surface: but it will be preferable to take, instead, a quantity which bears a constant ratio to it, namely, the acceleration which this pressure will, by acting for one unit of time, cause in a cubic unit of the fluid.

Investigation of the rectangular equations of the motion of fluids.

(74.) Conceive, then, a small parallelopiped to be inclosed by planes corresponding to the coordinates x, $x+h$; $y, y+k$; $z, z+l$; h, k, and l being extremely small. The pressure per unit of surface on that end whose ordinate is x, is p; but the area of that end is kl; therefore the actual pressure is pkl. The actual pressure on the other end is $kl\times$ the value of p corresponding to $x+h$, or it is $kl\times\left(p+\frac{dp}{dx}h\right)$. The former of these tends to push the parallelopiped forward in the direction of x: the latter tends to push it backward. The actual pressure, then, tending to push it backward, is $\frac{dp}{dx}hkl$; and as the volume of the parallelopiped is hkl, the accelerating force in the direction opposite to that in which x is measured is $\frac{dp}{dx}$. If there is acting an extraneous accelerating force, tending to urge the particles in the direction of x, and represented by X, then the real accelerating force in the direction of x is $\mathrm{X}-\frac{dp}{dx}$. Consequently, (MECHANICS, page 91,) $\frac{d^2x}{dt^2}=\mathrm{X}-\frac{dp}{dx}$. Similarly, $\frac{d^2y}{dt^2}=\mathrm{Y}-\frac{dp}{dy}$; $\frac{d^2z}{dt^2}=\mathrm{Z}-\frac{dp}{dz}$.

Equality of pressure in moving fluids requires investigation.

(75.) It is to be remarked, that here we conceive the quantity p to be the same in the three equations which we have just found. That this is true when a fluid is in equilibrium (or that fluids press equally in all directions) there is no doubt: indeed it can be shown to be a necessary consequence of the possibility of division of the fluid by planes in all directions, and of the perpendicularity of the pressure of the fluid on any such plane. It is not so self-evidently certain for fluids in variable motion. Without expressing any doubt of its truth, we wish at the same time to call the reader's attention to the difference of evidence for the principle in the different cases.

Investigation of the polar equations of the motion of fluids.

(76.) To apply this to the movement of the sea: let x be parallel to the axis of revolution of the earth, y directed towards the first point of Aries, and z at right angles to these. And put θ' for $\theta+u$, ϖ' for $\varpi+v$: r for the distance of any particle from the earth's centre. Then $x=r.\cos\theta'$, $y=r.\sin\theta'.\cos\overline{nt+\varpi'}$, $z=r.\sin\theta'.\sin\overline{nt+\varpi'}$. Our equations of motion, which depend on x, y, z, must be transformed into others depending on r, θ', ϖ'. We must, then, instead of $\frac{dp}{dx}$, put $\frac{dp}{dr}.\frac{dr}{dx}+\frac{dp}{d\theta'}.\frac{d\theta'}{dx}+\frac{dp}{d\varpi'}.\frac{d\varpi'}{dx}$: for $\frac{dp}{dy}$ we must put $\frac{dp}{dr}.\frac{dr}{dy}+\frac{dp}{d\theta'}.\frac{d\theta'}{dy}+\frac{dp}{d\varpi'}.\frac{d\varpi'}{dy}$; and for $\frac{dp}{dz}$ we must put $\frac{dp}{dr}.\frac{dr}{dz}+\frac{dp}{d\theta'}.\frac{d\theta'}{dz}+\frac{dp}{d\varpi'}.\frac{d\varpi'}{dz}$. And, in forming the quantities $\frac{dr}{dx}$, $\frac{d\theta'}{dx}$, &c., we must express r, θ', and ϖ', in terms of no variable quantities whatever, except x, y, and z. For then it is clear that we have $\frac{dp}{dx}$, &c. exactly in the same manner as if p was explicitly expressed in terms of x, y, and z. Now

$$r^2=x^2+y^2+z^2;$$

therefore

$$\frac{dr}{dx}=\frac{x}{r};\quad \frac{dr}{dy}=\frac{y}{r};\quad \frac{dr}{dz}=\frac{z}{r}.$$

Also

$$\tan\theta'=\frac{\sqrt{y^2+z^2}}{x}$$

differentiating, and observing that $\cos^2\theta'=\frac{x^2}{r^2}$,

$$\frac{d\theta'}{dx}=\frac{-\sqrt{y^2+z^2}}{r^2};\quad \frac{d\theta'}{dy}=\frac{xy}{r^2\sqrt{y^2+z^2}};\quad \frac{d\theta'}{dz}=\frac{xz}{r^2\sqrt{y^2+z^2}}.$$

And

$$\tan\overline{nt+\varpi'}=\frac{z}{y};\quad \cos^2\overline{nt+\varpi'}=\frac{y^2}{y^2+z^2}:$$

therefore

$$\frac{d\varpi'}{dx}=0;\quad \frac{d\varpi'}{dy}=\frac{-z}{y^2+z^2};\quad \frac{d\varpi'}{dz}=\frac{y}{y^2+z^2}.$$

Substituting these, the equations of motion become

$$\begin{aligned}
&\frac{dp}{dr}\cdot\frac{x}{r}-\frac{dp}{d\theta'}\cdot\frac{\sqrt{y^2+z^2}}{r^2} &&=X-\frac{d^2x}{dt^2}\\
&\frac{dp}{dr}\cdot\frac{y}{r}+\frac{dp}{d\theta'}\cdot\frac{xy}{r^2\sqrt{y^2+z^2}}-\frac{dp}{d\varpi'}\cdot\frac{z}{y^2+z^2} &&=Y-\frac{d^2y}{dt^2}\\
&\frac{dp}{dr}\cdot\frac{z}{r}+\frac{dp}{d\theta'}\cdot\frac{xz}{r^2\sqrt{y^2+z^2}}+\frac{dp}{d\varpi'}\cdot\frac{y}{y^2+z^2} &&=Z-\frac{d^2z}{dt^2}.
\end{aligned}$$

(77.) From these we obtain

$$\begin{aligned}
\frac{dp}{dr}&=X\frac{x}{r}+Y\frac{y}{r}+Z\frac{z}{r}-\frac{x}{r}\cdot\frac{d^2x}{dt^2}-\frac{y}{r}\frac{d^2y}{dt^2}-\frac{z}{r}\cdot\frac{d^2z}{dt^2}\\
\frac{dp}{d\theta'}&=-X\sqrt{y^2+z^2}+\frac{Yxy+Zxz}{\sqrt{y^2+z^2}}+\frac{1}{\sqrt{y^2+z^2}}\left\{(y^2+z^2)\frac{d^2x}{dt^2}-xy\frac{d^2y}{dt^2}-xz\frac{d^2z}{dt^2}\right\}\\
\frac{dp}{d\varpi'}&=Zy-Yz+z\frac{d^2y}{dt^2}-y\frac{d^2z}{dt^2}.
\end{aligned}$$

Now

$$\begin{aligned}
x\frac{d^2x}{dt^2}+y\frac{d^2y}{dt^2}+z\frac{d^2z}{dt^2}&=\frac{d}{dt}\left(x\frac{dx}{dt}+y\frac{dy}{dt}+z\frac{dz}{dt}\right)-\left\{\left(\frac{dx}{dt}\right)+\left(\frac{dy}{dt}\right)^2+\left(\frac{dz}{dt}\right)^2\right\}\\
&=\frac{1}{2}\cdot\frac{d^2(r^2)}{dt^2}-\left(\frac{dr}{dt}\right)^2-r^2\left(\frac{d\theta'}{dt}\right)^2-r^2\sin^2\theta'\left(n+\frac{d\varpi}{dt}\right)^2:
\end{aligned}$$

therefore

$$-\frac{x}{r}\cdot\frac{d^2x}{dt^2}-\frac{y}{r}\cdot\frac{d^2y}{dt^2}-\frac{z}{r}\cdot\frac{d^2z}{dt^2}=-\frac{1}{2r}\cdot\frac{d^2(r^2)}{dt^2}+\frac{1}{r}\left(\frac{dr}{dt}\right)^2+r\left(\frac{d\theta'}{dt}\right)^2+r\sin^2\theta'\left(n+\frac{d\varpi}{dt}\right)^2.$$

And

$$\begin{aligned}
(y^2+z^2)\frac{d^2x}{dt^2}-xy\frac{d^2y}{dt^2}-xz\frac{d^2z}{dt^2}&=y\frac{d}{dt}\left(y\frac{dx}{dt}-x\frac{dy}{dt}\right)+z\frac{d}{dt}\left(z\frac{dx}{dt}-x\frac{dz}{dt}\right)\\
=r\sin\theta'\cos\overline{nt+\varpi'}\frac{d}{dt}&\left\{-r^2\cos\overline{nt+\varpi}.\frac{d\theta'}{dt}+r^2\sin\theta'\cos\theta'.\sin\overline{nt+\varpi}.\left(n+\frac{d\varpi'}{dt}\right)\right\}\\
+r\sin\theta'\sin\overline{nt+\varpi'}.\frac{d}{dt}&\left\{-r^2\sin\overline{nt+\varpi'}\frac{d\theta'}{dt}-r^2\sin\theta'\cos\theta'.\cos\overline{nt+\varpi'}\left(n+\frac{d\varpi'}{dt}\right)\right\};
\end{aligned}$$

therefore

$$\begin{aligned}
&\frac{1}{\sqrt{y^2+z^2}}\left\{(y^2+z^2)\frac{d^2x}{dt^2}-xy\frac{d^2y}{dt^2}-xz\frac{d^2z}{dt^2}\right\}\\
&=-\cos\overline{nt+\varpi'}.\frac{d}{dt}\left(r^2\cos\overline{nt+\varpi'}.\frac{d\theta'}{dt}\right)-\sin\overline{nt+\varpi'}\frac{d}{dt}\left(r^2\sin\overline{nt+\varpi'}.\frac{d\theta'}{dt}\right)\\
&+\cos\overline{nt+\varpi'}.\frac{d}{dt}\left(r^2\sin\theta'\cos\theta'\left(n+\frac{d\varpi'}{dt}\right)\times\sin\overline{nt+\varpi'}\right)\\
&-\sin\overline{nt+\varpi'}.\frac{d}{dt}\left(r^2\sin\theta'.\cos\theta'\left(n+\frac{d\varpi'}{dt}\right)\times\cos\overline{nt+\varpi'}\right).
\end{aligned}$$

If for the moment we put U for $r^2\cos\overline{nt+\varpi'}.\frac{d\theta'}{dt'}$, V for $r^3\sin\overline{nt+\varpi'}.\frac{d\theta'}{dt}$, W for $r^2\sin\theta'.\cos\theta'\left(n+\frac{d\varpi'}{dt}\right)$, this expression becomes

$$-\frac{1}{r^2\frac{d\theta'}{dt}}\times\left\{U\frac{dU}{dt}+V\frac{dV}{dt}\right\}$$

$$+\frac{1}{r^2\sin\theta'\cos\theta'.\left(n+\frac{d\varpi'}{dt}\right)}\left\{W.\cos\overline{nt+\varpi'}.\frac{d}{dt}\left(W.\sin\overline{nt+\varpi'}\right)-W.\sin\overline{nt+\varpi}.\frac{d}{dt}\left(W.\cos\overline{nt+\varpi'}\right)\right\}$$

$$=-\frac{1}{2r^2\frac{d\theta'}{dt}}\times\frac{d}{dt}\left(U^2+V^2\right)+\frac{1}{r^2\sin\theta'.\cos\theta'.\left(n+\frac{d\varpi'}{dt}\right)}\times W^2.\frac{d}{dt}\left(nt+\varpi'\right)$$

$$=-\frac{1}{2r^2\frac{d\theta'}{dt}}.\frac{d}{dt}\left(r^4\left(\frac{d\theta'}{dt}\right)^2\right)+\frac{1}{r^2\sin\theta'.\cos\theta'.\left(n+\frac{d\varpi'}{dt}\right)}\times r^4.\sin^2\theta'.\cos^2\theta'.\left(n+\frac{d\varpi'}{dt}\right)^2\times\left(n+\frac{d\varpi'}{dt}\right)$$

$$=-\frac{d}{dt}\left(r^2\frac{d\theta'}{dt}\right)+r^2.\sin\theta'.\cos\theta'.\left(n+\frac{d\varpi'}{dt}\right)^2.$$

And

$$z\frac{d^2y}{dt^2}-y\frac{d^2z}{dt^2}=\frac{d}{dt}\left(z\frac{dy}{dt}-y\frac{dz}{dt}\right)$$

$$=\frac{d}{dt}\left\{r\sin\theta'.\sin\overline{nt+\varpi'}\frac{d}{dt}\left(r\sin\theta'.\cos\overline{nt+\varpi'}\right)-r\sin\theta'.\cos\overline{nt+\varpi'}\frac{d}{dt}\left(r\sin\theta'\sin\overline{nt+\varpi}\right)\right\}$$

$$=-\frac{d}{dt}\left\{r^2\sin^2\theta'\left(n+\frac{d\varpi'}{dt}\right)\right\}$$

$$=-2r\frac{dr}{dt}\sin^2\theta'\left(n+\frac{d\varpi'}{dt}\right)-2r^2\sin\theta'.\cos\theta'\frac{d\theta'}{dt}\left(n+\frac{d\varpi'}{dt}\right)-r^2\sin^2\theta'.\frac{d^2\varpi'}{dt^2}.$$

Polar equations of the motion of fluids.

Substituting these, our equations become

$$\frac{dp}{dr}=X\frac{x}{r}+Y\frac{y}{r}+Z\frac{z}{r}-\frac{1}{2r}.\frac{d^2(r^2)}{dt^2}+\frac{1}{r}\left(\frac{dr}{dt}\right)^2+r\left(\frac{d\theta'}{dt}\right)^2+r\sin^2\theta'\left(n+\frac{d\varpi'}{dt}\right)^2$$

$$\frac{dp}{d\theta'}=-X\sqrt{y^2+z^2}+\frac{Yxy+Zxz}{\sqrt{y^2+z^2}}-\frac{d}{dt}\left(r^2\frac{d\theta'}{dt}\right)+r^2\sin\theta'\cos\theta'\left(n+\frac{d\varpi'}{dt}\right)^2$$

$$\frac{dp}{d\varpi'}=Zy-Yz-2r\frac{dr}{dt}\sin^2\theta'\left(n+\frac{d\varpi'}{dt}\right)-2r^2\sin\theta'.\cos\theta'.\frac{d\theta'}{dt}\left(n+\frac{d\varpi'}{dt}\right)-r^2\sin^2\theta'\frac{d^2\varpi'}{dt^2}.$$

Limited equations applicable to the motion of the sea.

(78.) The equations as we have just given them are complete. But, in conformity with the remarks in (69.), we may considerably reduce the number of terms. For, if we omit the motion in the direction perpendicular to the surface, we may entirely omit $\frac{dr}{dt}$ and $\frac{d^2r}{dt^2}$. Also, as the tidal oscillation is very small in proportion to the earth's dimensions, we may in every case omit the squares of $\frac{d\theta'}{dt}$ and $\frac{d\varpi'}{dt}$ and their product. Thus the equations become

$$\frac{dp}{dr}=X\frac{x}{r}+Y\frac{y}{r}+Z\frac{z}{r}+r\sin^2\theta'\left(n^2+2n\frac{d\varpi'}{dt}\right)$$

$$\frac{dp}{d\theta'}=-X\sqrt{y^2+z^2}+\frac{Yxy+Zxz}{\sqrt{y^2+z^2}}-r^2\frac{d^2\theta'}{dt^2}+r^2\sin\theta'.\cos\theta'.\left(n^2+2n\frac{d\varpi'}{dt}\right)$$

$$\frac{dp}{d\varpi'}=Zy-Yz-2r^2\sin\theta'\cos\theta'\frac{d\theta'}{dt}.n-r^2\sin^2\theta'\frac{d^2\varpi'}{dt^2}.$$

But θ' enters only as the representative of $\theta+u$: so that, supposing u small, $\frac{dp}{d\theta'}$ will not sensibly differ from $\frac{dp}{d\theta}$; $\sin\theta'$ and $\cos\theta'$ in the factors will not sensibly differ from $\sin\theta$ and $\cos\theta$; and $\frac{d\theta'}{dt}$ is $=\frac{du}{dt}$, because θ does not depend on the time. Also $\frac{dp}{d\varpi'}$ will not sensibly differ from $\frac{dp}{d\varpi}$, and $\frac{d\varpi'}{dt}=\frac{dv}{dt}$. Thus the equations of motion become

$$\frac{dp}{dr} = \mathrm{X}\frac{x}{r} + \mathrm{Y}\frac{y}{r} + \mathrm{Z}\frac{z}{r} + r\sin^2\theta\left(n^2 + 2n\frac{dv}{dt}\right)$$

$$\frac{dp}{d\theta} = -\mathrm{X}\sqrt{y^2+z^2} + \frac{\mathrm{Y}xy + \mathrm{Z}xz}{\sqrt{y^2+z^2}} - r^2\frac{d^2u}{dt^2} + r^2\sin\theta.\cos\theta.\left(n^2 + 2n\frac{dv}{dt}\right)$$

$$\frac{dp}{d\varpi} = \mathrm{Z}y - \mathrm{Y}z - 2r^2\sin\theta.\cos\theta.\frac{du}{dt}n - r^2\sin^2\theta\frac{d^2v}{dt^2}.$$

(79.) We shall now proceed to express the forces X, Y, Z. For convenience we shall divide each into two parts, $\mathrm{X}=\mathrm{X}'+\mathrm{X}''$, $\mathrm{Y}=\mathrm{Y}'+\mathrm{Y}''$, $\mathrm{Z}=\mathrm{Z}'+\mathrm{Z}''$: where X′, Y′, Z′, relate only to the attractions of the earth, and X″, Y″, Z″ only to those of the disturbing bodies. We shall also suppose p divided into three parts, p', p'', p''', of which the first is that part which depends on the earth's attraction and the factor n^2, the second depends only on the disturbing forces, and the third only on the differentials of u and v. And we shall put r' for the distance from the earth's centre to the surface of the undisturbed watery spheroid; so that $r'+w$ is the value of r, at the surface of the water as disturbed by the Tide. First we will remark, as a point particularly worthy of the reader's attention, that here we must not introduce what is usually called *centrifugal force*. For our equations proceed at once from the equations by rectangular co-ordinates, and in these the whole relations between the forces and the motions are absolutely included. The assertion of the existence of *centrifugal force* is in fact merely an assertion that, in order to maintain bodies or fluids in an assumed state of circular motion, a *centripetal* force must be applied. We shall soon see that the effects of centrifugal force, as regards the figure of the earth, are fully taken into account without introducing that expression at all. The point deserves a little more notice than has commonly been given to it in theories of the Figure of the Earth and similar subjects.

The forces divided into two parts.

The pressures divided into three parts.

Centrifugal force is not to be introduced.

(80.) The expressions for X′, Y′, Z′, or the attractions of the terrestrial spheroid on a particle of the sea, will be derived from those for Z′, X′, Y′, in Article 66. of the FIGURE OF THE EARTH, observing that here (in conformity with the notation used by Laplace in this investigation) we have taken x for the axis of rotation, instead of z, as in the FIGURE OF THE EARTH. Those expressions suppose the form of the terrestrial spheroid to be the form of equilibrium of its strata supposed fluid; which supposition is not infringed by our assumption that the depth of the sea is unequal, because the depth of the sea and its inequalities are very small in comparison with the earth's ellipticity. Taking the expressions referred to, and observing that m, by Article 62. of that treatise, $=\frac{3\pi}{\mathrm{T}^2}\cdot\frac{\mathrm{b}^3}{\phi(\mathrm{b})}$, and that ϕ (b) in Article 66.$=\frac{3\mathrm{M}}{4\pi}$, so that $m=\frac{4\pi^2\mathrm{b}^3}{\mathrm{T}^2\mathrm{M}}$; and remarking that, as T is the time of rotation, and n the angular velocity of rotation, $n\mathrm{T}=2\pi$, so that $\frac{4\pi^2}{\mathrm{T}^2}=n^2$, and m therefore $=\frac{n^2\mathrm{b}^3}{\mathrm{M}}$; we obtain

Forces depending on the earth's attraction and on rotation.

$$\mathrm{X}' = -\frac{\mathrm{M}x}{r^3} - x\frac{\mathrm{b}^2(3y^2+3z^2-2x^2)}{r^7}\left(\mathrm{Me} - \frac{n^2\mathrm{b}^3}{2}\right)$$

$$\mathrm{Y}' = -\frac{\mathrm{M}y}{r^3} - y\frac{\mathrm{b}^2(y^2+z^2-4x^2)}{r^7}\left(\mathrm{Me} - \frac{n^2\mathrm{b}^3}{2}\right)$$

$$\mathrm{Z}' = -\frac{\mathrm{M}z}{r^3} - z\frac{\mathrm{b}^2(y^2+z^2-4x^2)}{r^7}\left(\mathrm{Me} - \frac{n^2\mathrm{b}^3}{2}\right).$$

Substituting these in the expressions for $\frac{dp}{dr}$, &c. in (78.), and combining the terms which depend on n^2, we have

$$\frac{dp'}{dr} = -\frac{\mathrm{M}}{r^2} + \frac{\mathrm{b}^2(2-3\sin^2\theta)}{r^4}\left(\mathrm{Me} - \frac{n^2\mathrm{b}^3}{2}\right) + n^2 r\sin^2\theta$$

$$\frac{dp'}{d\theta} = +\frac{2\mathrm{b}^2\sin\theta\cos\theta}{r^3}\left(\mathrm{Me} - \frac{n^2\mathrm{b}^3}{2}\right) + n^2r^2\sin\theta.\cos\theta$$

$$\frac{dp'}{d\varpi} = 0.$$

Integrating these,

$$p' = \frac{\mathrm{M}}{r} + \frac{\mathrm{b}^2\left(\sin^2\theta - \frac{2}{3}\right)}{r^3}\left(\mathrm{Me} - \frac{n^2\mathrm{b}^3}{2}\right) + \frac{n^2r^2}{2}\sin^2\theta + \mathrm{C}.$$

If we conceive $r=r'+r''$, r' being the value of r at the surface of the undisturbed watery spheroid, and r'' a variable quantity (which at the surface$=w$), it will be unnecessary to insert r'' in any term but the first or largest term. Thus

$$p'=\frac{M}{r'}-\frac{Mr''}{r'^2}+\frac{Mb^2e}{r'^3}\left(\sin^2\theta-\frac{2}{3}\right)+\frac{n^2}{2}\left(r'^2\sin^2\theta-\frac{b^3}{r'^3}\sin^2\theta+\frac{2b^5}{3r'^3}\right)+C.$$

Pressure depending on the earth's attraction and on rotation.

Putting for r' in the first term its approximate value b $(1+e\sin^2\theta)$, and in the other terms b only, it becomes

$$p'=\frac{M}{b}-\frac{M}{b^2}r''-\frac{2}{3}\frac{Me}{b}+\frac{n^2b^2}{3}+C.$$

The whole of this, except the second term, is constant: and we may therefore write it, $p'=I-\frac{M}{b^2}r''$. And as $\frac{M}{b^2}$ =attraction of the earth nearly, $=g$ nearly, we may write it

$$p'=I-gr''.$$

(81.) Before leaving this part of the investigation we will remark that, if at any one place where $r''=0$ the pressure is 0 (that is, if the surface be free there), it will $=0$ at every place where $r''=0$, or where $r=r'$, or where the fluid has the external boundary which we have taken from the investigations of the Figure of the Earth. And thus our process in this article, conducted without mention of centrifugal force, leads to the same result as that which was based upon it.

(82.) The equations determining p'' will be

$$\frac{dp''}{dr}=X''\frac{x}{r}+Y''\frac{y}{r}+Z''\frac{z}{r}$$

$$\frac{dp''}{d\theta}=-X''\sqrt{y^2+z^2}+\frac{Y''xy+Z''xz}{\sqrt{y^2+z^2}}$$

$$\frac{dp''}{d\varpi}=Z''y-Y''z.$$

Relative co-ordinates of the sun or moon.

Now let S be the mass of the sun; D its distance from the earth's centre; D' its distance from the particle at x, y, z; s its right ascension; σ its declination. Then x' for the sun$=D\sin\sigma$; $y'=D\cos\sigma.\cos s$; $z'=D\cos\sigma.\sin s$;

$$x'-x=D\sin\sigma-r\cos\theta,$$

$$y'-y=D\cos\sigma.\cos s-r\sin\theta.\cos\overline{nt+\varpi},$$

$$z'-z=D\cos\sigma.\sin s-r\sin\theta.\sin\overline{nt+\varpi};$$

$$\sqrt{\{(x'-x)^2+(y'-y)^2+(z'-z)^2\}}=D'=\sqrt{\{D^2-2Dr(\sin\sigma.\cos\theta+\cos\sigma.\sin\theta.\cos\overline{nt+\varpi-s})+r^2\}};$$

and, preserving only the first power of r,

$$\frac{1}{\{(x'-x)^2+(y'-y)^2+(z'-z)^2\}^{\frac{3}{2}}}=\frac{1}{D'^3}=\frac{1}{D^3}\times\left\{1+\frac{3r}{D}(\sin\sigma.\cos\theta+\cos\sigma.\sin\theta.\cos\overline{nt+\varpi-s})\right\}.$$

Now the whole force which the sun exerts upon the particle at x, y, z, in the direction of x, is $\frac{x'-x}{D'}\times\frac{S}{D'^2}=\frac{S(x'-x)}{D'^3}$. But the whole of this is not disturbing force upon the water in regard to its movement upon the earth. In order to find this, we must, as in (25.), subtract the force which the sun exerts upon the earth's centre of gravity, which is the same as if the whole mass of the earth were collected at its centre, and is therefore $=\frac{Sx'}{D^3}$ in the direction of x. Subtracting this, we have

$$X''=\frac{S(x'-x)}{D'^3}-\frac{Sx'}{D^3}=Sx'\left(\frac{1}{D'^3}-\frac{1}{D^3}\right)-\frac{Sx}{D'^3}$$

Disturbing forces of the sun or moon.

Similarly

$$Y'=Sy'\left(\frac{1}{D'^3}-\frac{1}{D^3}\right)-\frac{Sy}{D'^3}$$

$$Z''=Sz'\left(\frac{1}{D'^3}-\frac{1}{D^3}\right)-\frac{Sz}{D'^3}.$$

(83.) The expressions at the beginning of last article therefore become

$$X''\frac{x}{r}+Y''\frac{y}{r}+Z''\frac{z}{r}=\frac{S}{r}(x'x+y'y+z'z)\left(\frac{1}{D'^3}-\frac{1}{D^3}\right)-\frac{Sr}{D'^3}$$

$$-X''\sqrt{y^2+z^2}+\frac{Y''xy+Z''xz}{\sqrt{y^2+z^2}}=\frac{S}{\sqrt{y^2+z^2}}\left(x.\overline{y'y+z'z}-x'.\overline{y^2+z^2}\right)\left(\frac{1}{D'^3}-\frac{1}{D^3}\right)$$

$$Z''y-Y''z \qquad\qquad =S.\overline{z'y-y'z}.\left(\frac{1}{D'^3}-\frac{1}{D^3}\right).$$

Substituting in these the values of x, y, z, in terms of r, θ, and ϖ, and those of x', y', z', in terms of D, σ, s; we find (retaining only the principal power of r),

$$\frac{dp''}{dr}=\frac{Sr}{D^3}\{3\,(\sin\sigma.\cos\theta+\cos\sigma.\sin\theta.\cos\overline{nt+\varpi-s})^2-1\}$$

$$\frac{dp''}{d\theta}=\frac{3Sr^2}{D^3}\{\sin\sigma.\cos\theta+\cos\sigma.\sin\theta.\cos\overline{nt+\varpi-s}\}.\{-\sin\sigma.\sin\theta+\cos\sigma.\cos\theta.\cos\overline{nt+\varpi-s}\}$$

$$\frac{dp''}{d\varpi}=-\frac{3Sr^2}{D^3}\{\sin\sigma.\cos\theta+\cos\sigma.\sin\theta.\cos\overline{nt+\varpi-s}\}\cos\sigma.\sin\theta.\sin\overline{nt+\varpi-s}.$$

Pressure produced by the sun or moon.

Integrating, $$p''=\frac{Sr^2}{2D^3}\{3(\sin\sigma.\cos\theta+\cos\sigma.\sin\theta.\cos\overline{nt+\varpi-s})^2-1\}.$$

It is unnecessary to add an arbitrary constant, since one has been attached to the expression for p', to which this is to be added.

(84.) In conformity with the remarks in (68.), no regard is to be given, in this expression, to the variation in the values of r arising from the difference in the depth of particles of water. Instead of r, therefore, we may put the elliptic value r', or even the polar radius b. (This amounts to the assumption, that the Tides upon a spheroid, so nearly spherical as the earth, will not sensibly differ from those upon a sphere.) Putting b for r, and adding p' and p'', we find,

Equations for the pressure depending on the motion of the sea.

$$p=I-gr''+\frac{3Sb^2}{2D^3}\{(\sin\sigma.\cos\theta+\cos\sigma.\sin\theta.\cos\overline{nt+\varpi-s})^2-\tfrac{1}{3}\}+p'''$$

where
$$\frac{dp'''}{dr}=2nr.\sin^2\theta.\frac{dv}{dt}$$

$$\frac{dp'''}{d\theta}=-r^2\frac{d^2u}{dt^2}+2nr^2\sin\theta.\cos\theta.\frac{dv}{dt}$$

$$\frac{dp'''}{d\varpi}=-2nr^2\sin\theta.\cos\theta\frac{du}{dt}-r^2\sin^2\theta.\frac{d^2v}{dt^2}.$$

At the surface of the water, $p=0$. But at the surface $r''=w$; and, by the equation of continuity (72.) $w=-\frac{d}{d\theta}(u\gamma)-u\gamma.\text{cotan}\,\theta-\gamma\frac{dv}{d\varpi}$. Hence the tidal equation for the surface of the water becomes

$$0=I+\frac{3Sb^2}{2D^3}\{(\sin\sigma.\cos\theta+\cos\sigma.\sin\theta.\cos\overline{nt+\varpi-s})^2-\tfrac{1}{3}\}-gw+p''';$$

where w and p''' are subject to the equations expressed above.

(85.) If we expand the middle term of the tidal equation, that equation becomes

$$0=I+\frac{Sb^2}{2D^3}(\tfrac{3}{2}\cos^2\sigma-1)\,(1-3\cos^2\theta)+\frac{3Sb^2}{4D^3}\sin 2\sigma.\sin 2\theta.\cos\overline{nt+\varpi-s}$$
$$+\frac{3Sb^2}{4D^3}\cos^2\sigma.\sin^2\theta.\cos\overline{2nt+2\varpi-2s}-gw+p'''.$$

For most purposes, we may consider the variation of the terms depending on S to be produced only by the variation of $\overline{nt+\varpi-s}$, and we may consider $\frac{d}{dt}(nt+\varpi-s)$ or $n-\frac{ds}{dt}$ as a constant $=n'$, or we may represent $nt+\varpi-s$ by $n't+\varpi$ (by changing, if necessary, the origin of the time). Some of the terms therefore of the equation, depending on the disturbing force, are constant: some multiply $\cos\overline{n't+\varpi}$; and some multiply $\cos\overline{2n't+2\varpi}$. In strictness we ought to consider that σ and D are both variable; but they may be expressed in series of sines and cosines of multiples of the time; and when combined with $\cos\overline{n't+\varpi}$ and $\cos\overline{2n't+2\varpi}$ they will produce cosines of other arcs in which the coefficient of t is different, but that of ϖ is the same. The most general form therefore for one of the terms will be

General term of the pressure produced by the disturbing forces.

$$\Theta.\cos\overline{it+k\varpi},$$

where, for the first of the important terms, $\Theta=\text{A}.\sin 2\theta$, $k=1$, and $i=n'$, or differs little from n; for the second $\Theta=\text{B}.\sin^2\theta$, $k=2$, and $i=2n'$; and where, in the terms in general, k has no values but 0, 1, 2, but i may have any value between wide limits, and Θ may have any multiples of $\sin 2\theta$ and $\sin^2\theta$ added together.

(86.) The equation between w, u, and v; those between p''', u, and v; and that between w, p''', and the terms arising from the disturbing force; being all linear, we may take the terms arising from the disturbing force separately, and, finding the solution for each term, we may add all together. It will be sufficient, therefore, to proceed with the solution of the equation

$$0=\Theta\cos\overline{it+k\varpi}-gw+p'''.$$

Limited equations for the pressure, as depending on all causes.

(87.) Now we may remark, that the equation for $\frac{dp'''}{dr}$ may be neglected, not because its terms are small, but because the variation of r to which they apply is insignificant. The reasoning of (68.) applies entirely to this; but the reader may see the same thing in the solution of the equations for p''. For, after having obtained the value of p'' by means of three equations $\left(\text{for } \frac{dp''}{dr}, \frac{dp''}{d\theta}, \text{and } \frac{dp''}{d\varpi}\right)$, we have put b for r, thereby implying that the variations of r are insensible; and we have thus obtained exactly the same expression as if we had put b for r in the equations for $\frac{dp''}{d\theta}$ and $\frac{dp'}{d\varpi}$ and had neglected the equation for $\frac{dp''}{dr}$; although the terms of $\frac{dp''}{dr}$ are comparable to those of $\frac{dp''}{d\theta}$ and $\frac{dp''}{d\varpi}$. In like manner we shall here put b for r and neglect $\frac{dp'''}{dr}$. Thus we have

$$\frac{dp'''}{d\theta}=-\text{b}^2\frac{d^2u}{dt^2}+2n\text{b}^2.\sin\theta.\cos\theta.\frac{dv}{dt}$$

$$\frac{dp'''}{d\varpi}=-2n\text{b}^2.\sin\theta.\cos\theta\frac{du}{dt}-\text{b}^2\sin^2\theta\frac{d^2v}{dt^2}$$

$$w=-\frac{d}{d\theta}(u\gamma)-u\gamma.\text{cotan}\,\theta-\gamma\frac{dv}{d\varpi}$$

$$0=\Theta\cos\overline{it+k\varpi}-gw+p'''$$

Popular explanation of the terms introduced by considering the earth's rotation.

(88.) The terms multiplying n, it is to be remarked, are produced entirely by introducing the consideration of the earth's rotation. Of the origin of these terms the following popular explanation (which, however, is sufficiently accurate to be used as a basis of calculation) may be given. Suppose a particle of water to be running towards the equator (that is, suppose that u is increasing). By this motion, it is proceeding from a small parallel towards a large one, or from a place in which the movement from west to east (produced by the earth's rotation) is small, to one in which the movement from west to east is large. It is, therefore, advancing to a part of the earth whose movement towards the east is more rapid than its own, and therefore it tends to lag behind the movement of that part of the earth. Consequently there will be, in the expression for $\frac{d^2v}{dt^2}$, (which is the acceleration towards the east,) a term depending on u, which denotes that there is a retarding force when u is increasing: that is, $\frac{d^2v}{dt^2}$ will be expressed by terms of which one is a negative multiple of $\frac{du}{dt}$. Again, suppose a particle of water to be running towards the east (that is, suppose that v is increasing). The angular velocity of this particle is greater than the earth's angular velocity: therefore the centrifugal force is greater than the centrifugal force would have been if it had had no such motion towards the east; there is therefore, from this cause, an addition of centrifugal force; and this addition (like the original centrifugal force) is in the direction of the radius of the parallel, and is perpendicular to the earth's axis; resolving this into a vertical and a horizontal force, the horizontal force is directed towards the equator, or tends to increase u: that is, $\frac{d^2u}{dt^2}$ will be expressed by terms of which one is a positive multiple of $\frac{dv}{dt}$.

(89.) A general solution of the equations of (87.) is scarcely to be hoped for; it is a matter of difficulty to find, in a very limited case, a particular integral which will satisfy them. We shall begin, in the manner of Laplace, by trying whether they cannot be satisfied by expressions of the following form:

Assumption of the form of solution as regards the longitude.

$$w=a.\cos\overline{it+k\varpi}$$
$$u=b.\cos\overline{it+k\varpi}$$
$$v=c.\sin\overline{it+k\varpi}$$
$$p'''=a'''.\cos\overline{it+k\varpi}$$

where a, b, c, a'', are functions of θ only.

(90.) Substituting these expressions, the equations become

$$\cos\overline{it+k\varpi}\cdot\frac{da'''}{d\theta}=\ +\mathrm{b}^2 b.i^2\cos\overline{it+k\varpi}\ \ +2n\,\mathrm{b}^2.\sin\theta.\cos\theta.c.i.\cos\overline{it+k\varpi}$$
$$-k.a'''.\sin\overline{it+k\varpi}=\ +2n\,\mathrm{b}^2\sin\theta.\cos\theta.b.i.\sin\overline{it+k\varpi}\ \ +\mathrm{b}^2.\sin^2\theta.c.i^2.\sin\overline{it+k\varpi}$$
$$a.\cos\overline{it+k\varpi}=\ -\frac{d\,(b\gamma)}{d\theta}\cos\overline{it+k\varpi}\ \ -b\gamma.\mathrm{cotan}\,\theta.\cos\overline{it+k\varpi}\ \ -\gamma ck.\cos\overline{it+k\varpi}$$
$$0\qquad=\Theta.\cos\overline{it+k\varpi}\ \ -ga.\cos\overline{it+k\varpi}\ \ +a'''.\cos\overline{it+k\varpi}$$

or

$$\frac{da'''}{d\theta}=\mathrm{b}^2 i^2.b+2n\,\mathrm{b}^2 i.\sin\theta.\cos\theta.c$$
$$-ka'''=2n\,\mathrm{b}^2 i.\sin\theta.\cos\theta.b+\mathrm{b}^2 i^2.\sin^2\theta.c$$
$$a=-\frac{d\,(b\gamma)}{d\theta}-b\gamma\,\mathrm{cotan}\,\theta-\gamma ck$$
$$0=\Theta-g\,a+a'''.$$

The assumption is sufficient.

It is clear that our assumptions have satisfied the equations as far as regards ϖ; for every term containing ϖ has vanished upon making the substitution. Moreover we have four differential equations by which to determine four unknown quantities, and these (whatever practical difficulties we may find) are, theoretically, sufficient for their determination. It is therefore certain that a solution may be found, in the form which is expressed by the four assumptions for w, u, v, and p'''.

Inferences from the form assumed.

(91.) Before proceeding further with the solution, we may draw a few inferences from the form of the expressions that we have already found. First, since the velocity of the water in the direction of the meridian is $\mathrm{b}\frac{du}{dt}$ or $-\mathrm{b}bi\sin\overline{it+k\varpi}$, and the velocity perpendicular to the meridian is $\mathrm{b}\sin\theta.\frac{dv}{dt}$, or $\mathrm{b}c.\sin\theta.i.\cos\overline{it+k\varpi}$, the water at any given place, except in certain limited cases, is never at rest, but the direction in which it runs changes perpetually. The expression for its whole velocity at any instant is $\mathrm{b}\sqrt{\left(\left(\frac{du}{dt}\right)^2+\sin^2\theta\left(\frac{dv}{dt}\right)^2\right)}$, or $\mathrm{b}\sqrt{(b^2 i^2.\sin^2\overline{it+k\varpi}+c^2\sin^2\theta.i^2.\cos^2\overline{it+k\varpi})}$ and the tangent of the angle which its course makes with the meridian at that instant is $\dfrac{\sin\theta\frac{dv}{dt}}{\frac{du}{dt}}$, or $\dfrac{-c\sin\theta}{b}\,\mathrm{cotan}\,\overline{it+k\varpi}$. This is the same kind of rotation to which we have alluded in (9.): but we shall see hereafter that the latter arises from a different cause.

The direction of the tide-current revolves.

High or low water in solar or lunar tide will occur at the transit of the sun or moon.

(92.) Secondly, since the term $\Theta.\cos\overline{it+k\varpi}$ produces a term w of the form $a.\cos\overline{it+k\varpi}$ (where a may be positive or negative), and since, for the principal tidal terms in p'', $\cos\overline{it+k\varpi}$ will have the form $\cos\overline{nt+\varpi-s}$, or $\cos\overline{2nt+2\varpi-2s}$, which terms have their maximum or minimum values when $s=nt+\varpi$, or when the sun's distance from the fixed meridian = the distance of the place from the fixed meridian, or when the sun is on the meridian of the place: it follows that either the high or the low water of the solar tide must occur, in conformity with this theory, exactly when the sun is on the meridian. A similar law applies to the time of the lunar tide.

Time of high water altered by the variation of the forces.

(93.) Thirdly, if a factor of Θ (which depends on the sun's linear distance and declination) is expressed by $1+f\cos i't$, where i' is small (or where the term $f\cos i't$ varies slowly), then $\Theta\cos\overline{it+k\varpi}$ will become

$$\Theta\cos\overline{it+k\varpi}+\frac{\Theta f}{2}\cos\overline{(i+i')\,t+k\varpi}+\frac{\Theta f}{2}\cos\overline{(i-i')\,t+k\varpi}:$$

and since a in the expression for w depends on i, we must use $a+\frac{da}{di}i'$ in the second term, and $a-\frac{da}{di}i'$ in the third term; and the expression for w will be

$$a \cos \overline{it+k\varpi}+\frac{f}{2}\left(a+\frac{da}{di}i'\right) \cos \overline{(i+i')\,t+k\varpi}+\frac{f}{2}\left(a-\frac{da}{di}i'\right) \cos \overline{(i-i')\,t+k\varpi}$$

or

$$a\,(1+f \cos i'\,t) \cos \overline{it+k\varpi}-i'\frac{da}{dt}.\,f \sin i'\,t.\,\sin \overline{it+k\varpi}.$$

The time of high water on any given day will not now be the same as before; for, before, it occurred when $it+k\varpi=0$ or 180°, but now it occurs when

$$\tan \overline{it+k\varpi}=\frac{i'.\frac{da}{dt}.\,f.\,\sin i'\,t}{a\,(1+f\cos i'\,t)} \text{ nearly.}$$

Day of highest tide corresponds to the day of greatest force.

But the highest tide of all (the height being expressed by the square root of the sum of the squares of the coefficients of $\cos \overline{it+k\varpi}$ and $\sin \overline{it+k\varpi}$, as in (46.),) occurs when $\sqrt{\left\{a^2\,(1+f\cos i't)^2+i'^2.\left(\frac{da}{dt}\right)^2.f^2.\sin^2 i't\right\}}$ is maximum; and this is when $\cos i't=1$, or when the force which causes the tide is greatest. As far, therefore, as this theory applies, the highest solar tide ought to occur on the very day on which the solar force is greatest; and similarly the highest lunar tide ought to occur on the very day on which the lunar force is greatest.

Assumption of expression for the depth of the sea.

Laplace's method of solving the equations as depending on the latitude.

(94.) Returning now to our equations of (90.). The only way in which Laplace has attempted to solve them is the following. He has assumed, as the only law of depth on which a solution appears to be practicable, $\gamma=l-lq\cos^2\theta$. He has then shown that, taking separately the terms independent of $nt+\varpi-s$, those depending on $\cos \overline{nt+\varpi-s}$, and those depending on $\cos \overline{2nt+2\varpi-2s}$, it is possible to determine for each the value of q for which the equations can be solved, (the solution, in Laplace's manner, not being practicable for all values of q). He has shown that, to a certain degree of approximation, the same value of q will apply to the terms of different kinds. And in the simplest case (when $q=0$, or the depth is the same in all parts) he has shown that the terms in the height of the water depending on $\cos \overline{nt+\varpi-s}$ will be insensible, or the diurnal tide will be insensible. We now proceed (although by a method different in its principal parts from Laplace's) to obtain equivalent results.

(95.) From the first and second of the equations in (90.) we find

$$b=\frac{-i.\,\sin\theta.\frac{da'''}{d\theta}-2kn\cos\theta.\,a'''}{\mathrm{b}^2\,i.\,\sin\theta.(4n^2\cos^2\theta-i^2)},\qquad c=\frac{2n.\,\sin\theta.\,\cos\theta.\frac{da'''}{d\theta}+i\,k.a'''}{\mathrm{b}^2\,i.\,\sin^2\theta.\,(4n^2.\cos^2\theta-i^2)}.$$

Substituting these values in the third, which may be put in the form

$$a.\,\sin\theta=-\frac{d}{d\theta}\,(\gamma.b.\,\sin\theta)-\gamma.k.c.\,\sin\theta$$

we obtain

$$a.\,\sin\theta=\frac{d}{d\theta}\left\{\gamma.\frac{i.\,\sin\theta.\frac{da'''}{d\theta}+2kn.\,\cos\theta.\,a'''}{\mathrm{b}^2\,i.\,(4n^2.\,\cos^2\theta-i^2)}\right\}-\gamma.\frac{2kn.\,\sin\theta.\,\cos\theta.\frac{da'''}{d\theta}+ik^2.\,a'''}{\mathrm{b}^2\,i.\,\sin\theta.\,(4n^2.\,\cos^2\theta-i^2)}.$$

The equations reduced to one differential equation.

But from the fourth equation,

$$\Theta.\,\sin\theta=g.a.\,\sin\theta-a'''.\,\sin\theta.$$

Substituting in this last the value of $a.\,\sin\theta$ just found, we finally obtain

$$\Theta\ \mathrm{n}\,\theta=\frac{g}{\mathrm{b}^2\,i}.\frac{d}{d\theta}\left\{\gamma.\frac{i.\,\sin\theta.\frac{da''}{d\theta}+2kn.\,\cos\theta.\,a'''}{4n^2.\,\cos^2\theta-i^2}\right\}-\frac{g}{\mathrm{b}^2 i}.\gamma.\frac{2kn.\,\sin\theta.\,\cos\theta.\frac{da'''}{d\theta}+ik^2.\,a'''}{\sin\theta.\,(4n^2\cos^2\theta-i^2)}-a'''\sin\theta$$

a linear differential equation of the second order, in which the only unknown quantity is a'''.

(96.) If we perform the differentiation and multiply by $\sin\theta.\,(4n^2.\cos^2\theta-i^2)^2$, the equation becomes

$$\begin{aligned}\Theta.\,\sin^2\theta.\,(4n^2.\,\cos^2\theta-i^2)^2=&\ \frac{g}{\mathrm{b}^2 i}.\frac{d\gamma}{d\theta}.\,(4n^2\cos^2\theta-i^2)\,.\,(i.\,\sin^2\theta.\,\frac{da'''}{d\theta}+2kn.\,\sin\theta.\,\cos\theta.\,a''')\\ &+\frac{g}{\mathrm{b}^2 i}.\gamma.\left\{\begin{aligned}&i.\,\sin^2\theta.\,(4n^2.\,\cos^2\theta-i^2).\frac{d^2a'''}{d\theta^2}+i.\,\sin\theta.\,\cos.\,\theta\,(8n^2\sin^2\theta+4n^2\cos^2\theta-i^2)\,\frac{da'''}{d\theta}\\ &+\,(i^2k^2+2i^2kn.\,\sin^2\theta-4i\,k^2n^2.\,\cos^2\theta+8kn^3.\,\sin^2\theta.\,\cos^2\theta)\,.a'''\end{aligned}\right\}\\ &-\sin^2\theta.\,(4n^2.\,\cos^2\theta-i^2)^2.\,a'''\end{aligned}$$

If, with Laplace, we suppose $\gamma = l . (1 - q . \cos^2 \theta)$, $\frac{d\gamma}{d\theta} = 2lq . \sin\theta . \cos\theta$; and the equation takes the following form; in which we may remark that the factors of Θ, a''', and $\frac{d^2 a'''}{d\theta^2}$, contain only even powers of $\cos\theta$; and that the factor of $\frac{da'''}{d\theta}$ contains only odd powers of $\cos\theta$, multiplied by $\sin\theta$.

Expansion of differential equation with assumed expression for the depth.

$$\Theta \times \{ i^4 + (-8i^2 n^2 - i^4) \cos^2\theta + (16n^4 + 8i^2 n^2) \cos^4\theta - 16n^4 \cos^6\theta \} =$$

$$\frac{d^2 a'''}{d\theta^2} \times \frac{g}{\text{b}^2} \times \left\{ -i^2 l + (4ln^2 + i^2 l + i^2 lq) \cos^2\theta + (-4ln^2 - 4ln^2 q - i^2 lq) \cos^4\theta + 4ln^2 q \cos^6\theta \right\}$$

$$+ \frac{da'''}{d\theta} \times \frac{g}{\text{b}^2} \times \cos\theta . \sin\theta \times \left\{ (8ln^2 - 2i^2 lq - i^2 l) + (3i^2 lq - 4ln^2) \cos^2\theta - 4ln^2 q \cos^4\theta \right\}$$

$$+ a''' \times \frac{g}{\text{b}^2} \times \left\{ (i^2 k^2 l + 2ikln) + \left(\frac{8kln^3}{i} - 2ikln - 4k^2 ln^2 - 6iklnq - i^2 k^2 lq \right) \cos^2\theta \right.$$

$$\left. + \left(-\frac{8kln^3}{i} + \frac{8kln^3 q}{i} + 4k^2 ln^2 q . + 6iklnq \right) \cos^4\theta - \frac{8kln^3 q}{i} \cos^6\theta \right\}$$

$$+ a''' \times \{ -i^4 + (8i^2 n^2 + i^4) \cos^2\theta + (-16n^4 - 8i^2 n^2) \cos^4\theta + 16 n^4 \cos^6\theta \}.$$

It is evident that this equation can always be solved by assuming for a''' a form similar to that for Θ multiplied by a series of powers of $\cos^2\theta$ with indeterminate coefficients. The same would have held if we had assumed for γ an expression consisting of a greater number of terms with even powers of $\cos\theta$.

We shall now proceed with some steps of the solution of this equation.

(97.) Omitting the first or constant term in the equation of (85.), which, in fact, is only an arbitrary constant, to be so determined with reference to the term gw that the whole mass of the fluid will not be altered, the next term is $\frac{\text{S}\,\text{b}^2}{2\text{D}^3} \left(\frac{3}{2} \cos^2\sigma - 1 \right) (1 - 3\cos^2\theta)$. This term does not contain ϖ at all, and therefore we must make $k = 0$. But as D is slowly variable, and as σ also is variable, the factor $\frac{\text{S}\,\text{b}^2}{2\text{D}^3} \left(\frac{3}{2} \cos^2\sigma - 1 \right)$ would, if expanded, consist of a series of terms like A cos it, where i is small. Comparing A cos it $(1 - 3\cos^2\theta)$ with $\Theta \cos \overline{it + k\varpi}$ we have $\Theta = \text{A}\ (1 - 3\cos^2\theta)$, $k = 0$, i a small number. Substituting for Θ and k, and retaining only the lowest power of i in each term, the equation becomes

Equation corresponding to slow changes of the disturbing force.

$$\text{A} \times (16n^4 \cos^4\theta - 64n^4 \cos^6\theta + 48n^4 \cos^8\theta) =$$

$$\frac{d^2 a'''}{d\theta^2} \times \frac{g}{\text{b}^2} \times \left\{ 4ln^2 \cos^2\theta + (-4ln^2 - 4ln^2 q) \cos^4\theta + 4ln^2 q \cos^6\theta \right\}$$

$$+ \frac{da'''}{d\theta} \times \frac{g}{\text{b}^2} \times \cos\theta . \sin\theta \times (8ln^2 - 4ln^2 \cos^2\theta - 4ln^2 q \cos^4\theta)$$

$$+ a''' \times (-16n^4 \cos^4\theta + 16n^4 \cos^6\theta).$$

Suppose

$$a''' = \text{B}_2 \cos^2\theta + \text{B}_4 \cos^4\theta + \text{B}_6 \cos^6\theta + \&\text{c}.$$

Solution in powers of the cosine of the latitude.

Forming the expressions for $\frac{da'''}{d\theta}$ and $\frac{d^2 a'''}{d\theta^2}$, and expanding all the even powers of $\sin\theta$ in terms of $\cos\theta$, and after substituting in the equation, making the coefficient of each power of $\cos\theta = 0$, we find

$$a''' = \text{A} \times \left\{ \frac{\text{b}^2 n^2}{gl} \cos^4\theta + \frac{2q}{3} . \frac{\text{b}^2 n^2}{gl} \cos^6\theta + \frac{\text{b}^2 n^2}{gl} \left(\frac{\text{b}^2 n^2}{10gl} + \frac{q^2}{2} \right) \cos^8\theta \right.$$

$$\left. + \left(\frac{\text{b}^2 n^2}{gl} \times \left(\frac{2}{25} + \frac{62}{15.35} q \right) + \frac{14}{35} q^2 \right) \frac{\text{b}^2 n^2}{gl} \cos^{10}\theta + \&\text{c}. \right\}.$$

And

$$a = \frac{\Theta}{g} + \frac{a'''}{g}$$

$$= \frac{\text{A}}{g} (1 - 3\cos^2\theta) + \frac{\text{A}}{g} \text{ multiplied by the series just found.}$$

This is the coefficient of cos it in the expression for w, the tidal elevation of the water (89.).

(98.) If we remark that the centrifugal force at the equator is expressed by $\text{b}n^2$, it is evident that $\frac{\text{b}n^2}{g}$ is the proportion of that centrifugal force to gravity, or is the quantity which in the Treatise on the

FIGURE OF THE EARTH we have called m. The fraction $\frac{b^2 n^2}{gl}$ is therefore $=\frac{m}{\frac{l}{b}}$, and is not small, therefore, except m or $\frac{1}{289}$ be smaller than the proportion of the depth of the sea to the earth's radius, which is expressed by $\frac{l}{b}$. The form of solution adopted above will not, therefore, strictly apply if the depth is very small, as the coefficients of the series will not converge. In that case, it will be advantageous to put the solution in this form:

$$a'''=C_0+C_1.l+C_2 l^2+C_3 l^3+\&c.,$$

where C_0, C_1, C_2, C_3, &c. are functions of θ: and to substitute in the equation, and make the coefficient of each power of $l=0$. Thus we shall have

Solution in powers of the depth of the sea.

$$+A(1-3\cos^2\theta)=-C_0$$

$$0=\frac{d^2 C_0}{d\theta^2}\times\frac{g}{b^2}\times\{4n^2\cos^2\theta+(-4n^2-4n^2q)\cos^4\theta+4n^2q\cos^6\theta\}$$

$$+\frac{dC_0}{d\theta}\times\frac{g}{b^2}\times\cos\theta.\sin\theta\times(8n^2-4n^2\cos^2\theta-4n^2q\cos^4\theta)$$

$$+C_1\times(-16n^4\cos^4\theta+16n^4\cos^6\theta);$$

from which

$$C_1 l=\frac{-Agl}{b^2 n^2}.\frac{3}{2}.\frac{1+\cos^2\theta+q\cos^2\theta-3q\cos^4\theta}{\cos^2\theta},$$

and so on, the determination of each successive term being effected in the same manner. Hence a''' is expressed by the series

$$-A(1-3\cos^2\theta)-A.\frac{gl}{b^2n^2}.\frac{3}{2}.\frac{1+\cos^2\theta+q\cos^2\theta-3q\cos^4\theta}{\cos^2\theta}+\&c.$$

and

$$a=\frac{\Theta}{g}+\frac{a'''}{g}=\frac{A(1-3\cos^2\theta)}{g}+\frac{a'''}{g}=$$

$$-\frac{A}{g}.\frac{l}{bm}.\frac{3}{2}.\frac{1+\cos^2\theta+q\cos^2\theta-3q\cos^4\theta}{\cos^2\theta}+\&c.$$

The series converges by powers of $\frac{l}{bm}$, and diverges by powers of $\cos^2\theta$. Algebraically speaking, therefore, it fails near the equator: but it is probable that it would apply so near to it that, in regard to physical interpretation, the failure would be unimportant.

(99.) The fluctuation of which we have treated includes all those which Laplace denominates "*les oscillations de la première espèce.*"

(100.) The second term depending on the disturbing force, in the equation of (85.), is $+\frac{3Sb^2}{4D^3}\sin 2\sigma.\sin 2\theta.\cos\overline{nt+\varpi-s}$, or $\frac{3Sb^2}{2D^3}\sin 2\sigma.\sin\theta.\cos\theta.\cos\overline{nt+\varpi-s}$, which we will call $E.\sin\theta.\cos\theta.\cos\overline{nt+\varpi-s}$. Comparing this with the general term assumed in (85.), we have

$$\Theta=E.\sin\theta.\cos\theta$$

$$k=1$$

$$i=n-\frac{ds}{dt}.$$

In the investigation on which we are about to enter, we shall consider E as constant, (its variation depending only on the changes of distance and declination of the luminary, which are slow,) and $\frac{ds}{dt}$ as insignificant. The last assumption gives us

$$i=n.$$

Substituting these values of k and i, in the equation of (96.), and dividing by n^4, it becomes $\left(\text{since}.\frac{gl}{b^2n^2}=\frac{l}{bm}\right)$

$$\Theta\times(1-\cos^2\theta)\times(1-4\cos^2\theta)^2=$$

Tides and Waves.

Equation corresponding to diurnal Tide.

$$\frac{d^2a'''}{d\theta^2}\times\frac{l}{\mathrm{b}m}\times\{-1+(5+q)\cos^2\theta+(-4-5q)\cos^4\theta+4q\cos^6\theta\}$$

$$+\frac{da'''}{d\theta}\times\frac{l}{\mathrm{b}m}\times\cos\theta.\sin\theta\times\{(7-2q)+(-4+3q)\cos^2\theta-4q\cos^4\theta\}$$

$$+a'''\times\frac{l}{\mathrm{b}m}\times\{3+(2-7q)\cos^2\theta+(-8+18q)\cos^4\theta-8q\cos^6\theta\}$$

$$-a'''\times(1-\cos^2\theta)\times(1-4\cos^2\theta)^2.$$

We shall solve this by the same process as that used in (98.)

(101.) Suppose then

$$a'''=\mathrm{F}_0+\mathrm{F}_1\frac{l}{\mathrm{b}m}+\mathrm{F}_2\frac{l^2}{\mathrm{b}^2m^2}+\&\text{c.};$$

$\mathrm{F}_0, \mathrm{F}_1, \mathrm{F}_2$, &c. being functions of θ. Substituting this in the equation, and making the coefficient of each power of $l=0$, the first comparison (or the comparison of terms independent of l) evidently gives

$$\Theta\times(1-\cos^2\theta)\times(1-4\cos^2\theta)^2=-\mathrm{F}_0\times(1-\cos^2\theta)\times(1-4\cos^2\theta)^2,$$

or

$$\mathrm{F}_0=-\Theta=-\mathrm{E}.\sin\theta.\cos\theta.$$

From this we have $\dfrac{d\mathrm{F}_0}{d\theta}=\mathrm{E}.(1-2\cos^2\theta)$, $\dfrac{d^2\mathrm{F}_0}{d\theta^2}=+4\mathrm{E}.\sin\theta.\cos\theta.$

The second comparison (or that of terms containing the first power of l) gives

$$0=\frac{d^2\mathrm{F}_0}{d\theta^2}\times\frac{l}{\mathrm{b}m}\times\{-1+(5+q)\cos^2\theta+(-4-5q)\cos^4\theta+4q\cos^6\theta\}$$

$$+\frac{d\mathrm{F}_0}{d\theta}\times\frac{l}{\mathrm{b}m}\times\cos\theta.\sin\theta\times\{(7-2q)+(-4+3q)\cos^2\theta-4q\cos^4\theta\}$$

$$+\ \mathrm{F}_0\ \times\frac{l}{\mathrm{b}m}\times\{3+(2-7q)\cos^2\theta+(-8+18q)\cos^4\theta-8q\cos^6\theta\}$$

$$-\ \mathrm{F}_1\ \times\frac{l}{\mathrm{b}m}\times(1-\cos^2\theta)\times(1-4\cos^2\theta)^2.$$

Substituting, in the three first lines, the expressions found for F_0, $\dfrac{d\mathrm{F}_0}{d\theta}$, and $\dfrac{d^2\mathrm{F}_0}{d\theta^2}$, the equation becomes

$$0=\mathrm{E}\times\frac{l}{\mathrm{b}m}\times\sin\theta.\cos\theta\times\{-2q+18q\cos^2\theta-48q\cos^4\theta+32q\cos^6\theta\}-\mathrm{F}_1\times\frac{l}{\mathrm{b}m}\times(1-\cos^2\theta)\times(1-4\cos^2\theta)^2,$$

or

$$0=-\mathrm{E}.\sin\theta.\cos\theta\times2q.(1-\cos^2\theta).(1-4\cos^2\theta)^2-\mathrm{F}_1\times(1-\cos^2\theta).(1-4\cos^2\theta)^2;$$

from which

$$\mathrm{F}_1=-2q.\mathrm{E}.\sin\theta.\cos\theta=+2q\,\mathrm{F}_0.$$

The form of the equation between F_1 and F_2, that between F_2 and F_3, that between F_3 and F_4, &c. will be exactly the same as the form of that between F_0 and F_1: and since the form of F_1 (considered as a function of θ) is exactly the same as that of F_0, the nature of the substitution in the equation will be the same, and therefore the relation of all the successive coefficients F_1, F_2, &c. will be the same. Thus we shall have

$$\mathrm{F}_2=2q\mathrm{F}_1=-4q^2.\mathrm{E}.\sin\theta.\cos\theta$$

$$\mathrm{F}_3=2q\mathrm{F}_2=-8q^3.\mathrm{E}.\sin\theta.\cos\theta,$$

and so on. The expression for a''', therefore, is

$$-\mathrm{E}\sin\theta.\ \cos\theta-\mathrm{E}\ \sin\theta.\cos\theta\left(\frac{2ql}{\mathrm{b}m}+\frac{4q^2l^2}{\mathrm{b}^2m^2}+\frac{8q^3l^3}{\mathrm{b}^3m^3}+\&\text{c.}\right)$$

$$=-\mathrm{E}\sin\theta\cos\theta-\frac{2q\dfrac{l}{\mathrm{b}m}\mathrm{E}\sin\theta.\cos\theta}{1-\dfrac{2ql}{\mathrm{b}m}};$$

and, therefore,

$$a=\frac{\Theta}{g}+\frac{a'''}{g}=-\frac{2q\dfrac{l}{\mathrm{b}m}}{1-\dfrac{2ql}{\mathrm{b}m}}.\frac{\mathrm{E}}{g}.\sin\theta\cos\theta,$$

Finite solution corresponding to diurnal tide.

an expression in a finite form. The expression for the elevation of the water is, therefore,

$$-\frac{2q\,\frac{l}{\mathrm{b}m}}{1-\frac{2ql}{\mathrm{b}m}}\cdot\frac{\mathrm{E}}{g}.\sin\theta.\cos\theta.\cos\overline{nt+\varpi-s}.$$

When the depth is uniform, there is no diurnal tide in height.

(102.) In article (96.) we assumed the depth of the water to be represented by $l(1-q\cos^2\theta)$. If, then, the depth of the water be uniform over the whole globe, $q=0$. In that case the expression just found for the elevation of the water vanishes for every value of θ and ϖ, or for every point on the earth's surface. Thus we obtain the most remarkable and most unexpected result, that if the depth of the sea is uniform, the diurnal tide (or that depending on $\overline{nt+\varpi-s}$) is insensible. For, the expression for its elevation absolutely vanishes when the depth of the water is everywhere the same.

But there is diurnal tide in motion.

(103.) This evanescence of the tide applies, however, only to the *elevation* of the water. The *horizontal motion* is not destroyed. For, the displacement of the water in the direction of the meridian is u, and therefore its velocity in the direction of the meridian is $\frac{du}{dt}=-ib\sin\overline{it+k\varpi}$, (89.), $=-nb.\sin\overline{nt+\varpi-s}$: its displacement in longitude is v, and therefore its velocity in the direction of the parallel is $\sin\theta.\frac{dv}{dt}=ic.\sin\theta.\cos\overline{it+k\varpi}$ $=n.c.\sin\theta.\cos\overline{nt+\varpi-s}$. Now, taking the expressions for b and c in (95.), and assuming $a'''=-\mathrm{E}.\sin\theta.\cos\theta$, (to which it is reduced when $q=0$,) and $\frac{da'''}{d\theta}=\mathrm{E}(1-2\cos^2\theta)$, we obtain $b=\frac{\mathrm{E}}{\mathrm{b}^2n^2}$, $c=-\frac{\mathrm{E}\cos\theta}{\mathrm{b}^2n^2\sin\theta}$: from which the velocity in the direction of the meridian $=\frac{-\mathrm{E}}{\mathrm{b}n}\sin\overline{nt+\varpi-s}$, and that in the direction of the parallel $=\frac{-\mathrm{E}}{\mathrm{b}n}\cos\theta.\cos\overline{nt+\varpi-s}$: and the whole velocity of the water, which is the square root of the sum of the squares of these quantities, $=\frac{\mathrm{E}}{\mathrm{b}^2n}\sqrt{1-\sin^2\theta.\cos^2\overline{nt+\varpi-s}}$, and the tangent of the angle which its course makes with the parallel $=\frac{1}{\cos\theta}\tan\overline{nt+\varpi-s}$. Thus we obtain the result, that at the equator the water moves only north and south, resting for an instant at the change of motion: on every other part of the earth the water is always moving with some velocity, but the current is perpetually changing its direction: at the pole, the velocity is constant, and the direction is always transverse to the meridian which passes through the luminary. The same remarks hold when the depth of the water is not uniform: as the expressions for a''', b, and c differ from those which apply when the depth is uniform, only by having the factor $\frac{\mathrm{E}}{1-\frac{2ql}{\mathrm{b}m}}$ instead of E.

Rules for the time of high and low water in the diurnal tide.

(104.) If the place of observation is north of the equator, $\sin\theta.\cos\theta$ is positive: and if the declination of the luminary is north, $\frac{3\mathrm{Sb}^2}{2\mathrm{D}^3}\sin 2\sigma$ or E is positive: and if the luminary is on the meridian of the place, $\cos\overline{nt+\varpi-s}$ is positive, and has its greatest value. Hence, when the depth is variable, the sign of the elevation at the transit of the luminary, if on the same side of the equator as the place of observation, will be the same as that of $-q$. If the water be shallower at the poles than at the equator, q in the expression $l(1-q\cos^2\theta)$ must be positive, and therefore low water occurs at the transit of the luminary. If the water be deeper at the poles, q is negative, and the high water occurs at transit.

(105.) The numerical values of all these quantities will be computed by the process of (31.) and (35.) The mean value of $\frac{\mathrm{Sb}^2}{2\mathrm{D}^3g}$ for the Sun is 0·2710 foot: for the Moon, 0·5959 foot. If $l=\frac{7}{5}$ of a mile, $\frac{l}{\mathrm{b}m}=\frac{1}{10}$.

(106.) The fluctuations of which we have now treated are called by Laplace "*les oscillations de la seconde espèce.*"

(107.) The third term depending on the disturbing force, in the equation of (85.), is $\frac{3\mathrm{Sb}^2}{4\mathrm{D}^3}\cos^2\sigma.\sin^2\theta.\cos\overline{2nt+2\varpi-2s}$, which we shall call $\mathrm{G}.\sin^2\theta.\cos\overline{2nt+2\varpi-2s}$. Comparing this with the general term assumed in (85.), we have

$$\Theta = \mathrm{G}\sin^2\theta$$
$$k = 2$$
$$i = 2n-2\frac{ds}{dt}=2n \text{ nearly}.$$

Tides and Waves.

Equation corresponding to semi-diurnal tide.

Substituting these values in the equation of (96.), and dividing by n^4, it becomes

$$16.\mathrm{G}.\ \sin^8\theta=\frac{d^2a'''}{d\theta^2}\times\frac{l}{\mathrm{b}m}\times\{-4+(8+4q)\cos^2\theta+(-4-8q)\cos^4\theta+4q\cos^6\theta\}$$

$$+\frac{da'''}{d\theta}\times\frac{l}{\mathrm{b}m}\times\cos\theta.\sin\theta\times\{(4-8q)+(-4+12q)\cos^2\theta-4q\cos^4\theta\}$$

$$+a'''\times\frac{l}{\mathrm{b}m}\times\{24+(-16-40q)\cos^2\theta+(-8+48q)\cos^4\theta-8q\cos^6\theta\}$$

$$-16.a'''.\sin^6\theta.$$

Dividing by 4 $\sin^4\theta$, this becomes

$$4.\mathrm{G}.\sin^4\theta=\frac{d^2a'''}{d\theta^2}\times\frac{l}{\mathrm{b}m}\times\{-1+q\cos^2\theta\}$$

$$+\frac{da'''}{d\theta}\times\frac{\cos\theta}{\sin\theta}\times\frac{l}{\mathrm{b}m}\times\{(1-2q)+q\cos^2\theta\}$$

$$+\frac{a'''}{\sin^2\theta}\times\frac{l}{\mathrm{b}m}\times\{6+(2-10q)\cos^2\theta+2q\cos^4\theta\}$$

$$-4a'''.\sin^2\theta.$$

Let

$$a'''=\mathrm{H}_0+\mathrm{H}_1\frac{l}{\mathrm{b}m}+\ \&\mathrm{c}.$$

Solution in powers of the depth of the sea.

Substituting this in the equation, and comparing the coefficients of the same power of $\frac{l}{\mathrm{b}m}$, the comparison of terms independent of l gives

$$4\mathrm{G}.\sin^4\theta=-4\mathrm{H}_0\sin^2\theta,$$

or

$$\mathrm{H}_0=-\mathrm{G}\sin^2\theta.$$

This gives

$$\frac{d\mathrm{H}_0}{d\theta}=-2\mathrm{G}\sin\theta\cos\theta\ ;\ \frac{d^2\mathrm{H}_0}{d\theta^2}=\mathrm{G}(2-4\cos^2\theta).$$

The comparison of terms multiplying the first power of l gives

$$0=\frac{d^2\mathrm{H}_0}{d\theta^2}\times\frac{l}{\mathrm{b}m}\times\{-1+q\cos^2\theta$$

$$+\frac{d\mathrm{H}_0}{d\theta}\times\frac{\cos\theta}{\sin\theta}\times\frac{l}{\mathrm{b}m}\times\{(1-2q)+q\cos^2\theta\}$$

$$+\frac{\mathrm{H}_0}{\sin^2\theta}\times\frac{l}{\mathrm{b}m}\times\{6+(2-10q)\cos^2\theta+2q\cos^4\theta\}$$

$$4\mathrm{H}_1\times\frac{l}{\mathrm{b}m}\times\sin^2\theta.$$

Substituting for H_0, $\frac{d\mathrm{H}_0}{d\theta}$, and $\frac{d^2\mathrm{H}_0}{d\theta^2}$, the values found above, we obtain

$$0=\mathrm{G}\times\{-8+16q.\cos^2\theta-8q.\cos^4\theta\}-4\mathrm{H}_1.\sin^2\theta,$$

or

$$\mathrm{H}_1=\mathrm{G}\times\frac{-8+16q.\cos^2\theta-8q.\cos^4\theta}{4\sin^2\theta}=2\mathrm{G}\times\frac{-1+2q.\cos^2\theta-q.\cos^4\theta}{\sin^2\theta}.$$

By a similar process H_2 will be formed from H_1. Then

$$a'''=-\mathrm{G}\sin^2\theta-2\mathrm{G}\times\frac{1-2q.\cos^2\theta+q.\cos^4\theta}{\sin^2\theta}.\frac{l}{\mathrm{b}m}+\ \&\mathrm{c}.$$

and

$$a=\frac{\Theta}{g}+\frac{a'''}{g}=-\frac{2\mathrm{G}}{g}\times\frac{1-2q.\cos^2\theta+q.\cos^4\theta}{\sin^2\theta}.\frac{l}{\mathrm{b}m}+\ \&\mathrm{c}.$$

If the depth is uniform, or $q=0$, a will $=-\frac{2\mathrm{G}}{g}.\frac{1}{\sin^2\theta}.\frac{l}{\mathrm{b}m}+\ \&\mathrm{c}.$

Law of depth which gives a finite solution.

(108.) In general, the value of a will be expressed by an infinite series, in which the terms converge by powers of $\frac{l}{\mathrm{b}m}$ and diverge by powers of $\sin^2\theta$. But in one case the solution can be put in a finite form. Suppose $q=1$, or the depth of the water, which $=l(1-q\cos^2\theta)$, to be expressed by $l.\sin^2\theta$. Then

$$H_1=-2G.\frac{1-2\cos^2\theta+\cos^4\theta}{\sin^2\theta}=-2G\frac{(1-\cos^2\theta)^2}{\sin^2\theta}=-2G.\sin^2\theta.$$

Now since the term $H_0=-G\sin^2\theta$ gave us $H_1=-2G\sin^2\theta$, the term $H_1=-2G\sin^2\theta$ would in like manner give us $H_2=-4G\sin^2\theta$; and so on. Thus we have

$$a'''=-G\sin^2\theta-2G\sin^2\theta.\frac{l}{bm}-4G\sin^2\theta\left(\frac{l}{bm}\right)^2-\&c.$$

$$=-G\sin^2\theta-G\sin^2\theta\frac{2\frac{l}{bm}}{1-\frac{2l}{bm}}$$

and

$$a=\frac{\Theta}{g}+\frac{a'''}{g}=-\frac{2G}{g}.\frac{l}{bm}.\frac{1}{1-\frac{2l}{bm}}\sin^2\theta.$$

The expression for the elevation of the water in this case is therefore

$$-\frac{2G}{g}.\frac{l}{bm}.\frac{1}{1-\frac{2l}{bm}}.\sin^2\theta.\cos\overline{2nt+2\varpi-2s}$$

and b and c, from the expressions in (95.), are respectively $\frac{1}{b^2n^2}.\frac{G}{1-\frac{2l}{bm}}.\text{cotan}\,\theta$ and $\frac{1}{b^2n^2}.\frac{G}{1-\frac{2l}{bm}}.\frac{1+\cos^2\theta}{2\sin^2\theta}$;

and the velocity of the water in the direction of the meridian $=-\frac{2}{bn}.\frac{G}{1-\frac{2l}{bm}}.\text{cotan}\,\theta.\sin\overline{2nt+2\varpi-2s}$, and that in the direction of the parallel $=\frac{2}{bn}.\frac{G}{1-\frac{2l}{bm}}.\frac{1+\cos^2\theta}{2\sin\theta}.\cos\overline{2nt+2\varpi-2s}.$

In this case, low water occurs at the transit of the luminary.

(109.) When the luminary is on the meridian, either above or below the horizon, $\cos\overline{2nt+2\varpi-2s}=1$, and the elevation of the water is expressed by $-\frac{2G}{g}.\frac{l}{bm}.\frac{1}{1-\frac{2l}{bm}}.\sin^2\theta$; or the elevation has its maximum negative value; that is, it is low water. We have already (16.) alluded to Newton's anticipation of this result; and we shall find it confirmed by investigations in our next section.

Laplace's solution in powers of the sine of latitude.

(110.) Laplace has solved the equation, on the supposition that the depth is uniform, in a manner equivalent to the following. Make $q=0$ in the equation of (107.), and put $1-\sin^2\theta$ for $\cos^2\theta$, and it becomes

$$\begin{aligned}4G.\sin^4\theta=&-\frac{d^2a'''}{d\theta^2}\times\frac{l}{bm}\\&+\frac{da'''}{d\theta}\times\frac{\cos\theta}{\sin\theta}\times\frac{l}{bm}\\&+\frac{a'''}{\sin^2\theta}\times\frac{l}{bm}\times(8-2\sin^2\theta)\\&-4a'''.\sin^2\theta.\end{aligned}$$

Since $ga=\Theta+a'''=G\sin^2\theta+a'''$,

assume $$ga=K_2\sin^2\theta+K_4\sin^4\theta+\ \&c.\ +K_{2k}\sin^{2k}\theta+K_{2k+2}\sin^{2k+2}\theta+\ \&c.$$

or $$a'''=(K_2-G)\sin^2\theta+K_4\sin^4\theta+\ \&c.\ +K_{2k}\sin^{2k}\theta+\ \&c.$$

Substitute this in each term of the equation above, reducing the even powers of $\cos\theta$ into expressions depending on $\sin\theta$; then comparing the coefficients of successive powers of $\sin\theta$, we have

$$\begin{aligned}8(K_2-G)&=0\\12(K_4-K_4)&=0\end{aligned}$$

$$(-16K_6+10K_4)\frac{l}{bm}-4K_2=0$$

$$(-40K_8+28K_6)\frac{l}{bm}-4K_4=0$$

and generally, after the two first,

$$\{-(4k^2+12k)K_{2k+4}+(4k^2+6k)K_{2k+2}\}\frac{l}{bm}-4K_{2k}=0.$$

The first equation determines K_2; the second leaves K_4 absolutely indeterminate; the other equations determine in succession each of the succeeding coefficients from those preceding.

Explanation of the indeterminateness of one coefficient.

(111.) The indeterminateness of K_4 is a circumstance that admits of very easy interpretation. It is one of the arbitrary constants in a complete solution of the equation. It shows that we may give to K_4 any value that we please, even if $G=0$; and then, provided that we accompany our arbitrary K_4 with the corresponding values of K_6, K_8, &c., we shall have a series which expresses a value of ga that will satisfy the equation *when there is no external disturbing force whatever*, and which therefore may be added, multiplied by any number, to the expression determined as corresponding to a given force. In the next Section we shall find several instances exactly similar to this. Yet this obvious view of the interpretation of this circumstance appears to have escaped Laplace, and he has actually persuaded himself to adopt the following process. Putting the general equation among the coefficients into the form

$$\frac{K_{2k+2}}{K_{2k}}=\cfrac{2\frac{bm}{l}}{(2k^2+3k)-(2k^2+6k)\frac{K_{2k+4}}{K_{2k+2}}}$$

Error in Laplace's process.

he has unwarrantably conceived that this must apply when $k=1$ for the determination of K_4; and thus, applying the same equation to each quotient of terms which occurs in the denominator of the fraction, he finds

$$\frac{K_4}{K_2}=\cfrac{2\frac{bm}{l}}{2.1^2+3.1-(2.1^2+6.1)\times\cfrac{\frac{2bm}{l}}{2.2^2+3.2-(2.2^2+6.2)\times\cfrac{2\frac{bm}{l}}{2.3^2+3.3-\&c.}}}$$

in an infinite continued fraction. And upon this he founds some numerical calculations, adapted to different suppositions of the depth of the sea. We state, as a thing upon which no person, after examination, can have any doubt, that this operation is entirely unfounded.

Correction of Laplace's process.

(112.) In conformity with the remarks that we have just made, Laplace ought to have determined the series for ga which will satisfy the equations

$$0=-\frac{d^2a'''}{d\theta^2}\times\frac{l}{bm}+\frac{da'''}{d\theta}\times\frac{\cos\theta}{\sin\theta}\times\frac{l}{bm}+\frac{a'''}{\sin^2\theta}\times\frac{l}{bm}\times(8-2\sin^2\theta)-4a'''\sin^2\theta$$

$$ga=0+a'''$$

having a constant K_4 indeterminate; and then he ought to have added this series, either to a solution of the equation in (110). found with $K_4=0$, or to a solution in which any definite value has been used for K_4. The series which satisfies the equations above is easily found to be

$$K_4\times\left\{\sin^4\theta+\frac{5}{8}\sin^6\theta+\left(\frac{7}{16}-\frac{bm}{10.l}\right)\sin^8\theta+\left(\frac{189}{576}-\frac{79}{720}.\frac{bm}{l}\right)\sin^{10}\theta+\&c.\right.$$

Now when $\frac{bm}{l}=10$, (or the depth $=\frac{1}{2890}$ of the earth's radius) Laplace has found

$$a=\frac{G}{g}\{\sin^2\theta+20\cdot1862.\sin^4\theta+10\cdot1164.\sin^6\theta-13\cdot1047\sin^8\theta-15\cdot4488\sin^{10}\theta-\&c.\}.$$

He ought to have found

$$a=\frac{G}{g}\{\sin^2\theta+20\cdot1862.\sin^4\theta+10\cdot1164.\sin^6\theta-13\cdot1047\sin^8\theta-15\cdot4488\sin^{10}\theta-\&c.\}$$

$$+\frac{K_4}{g}\{\sin^4\theta+\frac{5}{8}\sin^6\theta+\left(\frac{7}{16}-\frac{10}{10}\right)\sin^8\theta+\left(\frac{189}{576}-\frac{790}{720}\right)\sin^{10}\theta+\&c.\}$$

where K_4 is absolutely arbitrary.

When $\frac{bm}{l}=\frac{5}{2}$, (or the depth $=\frac{1}{722}$ of the earth's radius,) Laplace has found

$$a=\frac{G}{g}\{\sin^2\theta+6\cdot1960.\sin^4\theta+3\cdot2474.\sin^6\theta+0\cdot7238.\sin^8\theta+0\cdot0919.\sin^{10}\theta+\&c.\}.$$

He ought to have found

$$a=\frac{G}{g}\{\sin^2\theta+6\cdot1960.\sin^4\theta+3\cdot2474.\sin^6\theta+0\cdot7238\sin^8\theta+0\cdot0919\sin^{10}\theta+\&c.\}$$
$$+\frac{K_4}{g}\left\{\sin^4\theta+\frac{5}{8}\sin^6\theta+\left(\frac{7}{16}-\frac{5}{2.10}\right)\sin^8\theta+\left(\frac{189}{576}-\frac{79}{720}.\frac{5}{2}\right)\sin^{10}\theta+\&c.\right\}.$$

When $\frac{bm}{l}=\frac{5}{4}$, (or the depth $=\frac{1}{361}$ of the earth's radius,) Laplace has found

$$a=\frac{G}{g}\{\sin^2\theta+0\cdot7504.\sin^4\theta+0\cdot1566.\sin^6\theta+0\cdot0157.\sin^8\theta+0\cdot0009.\sin^{10}\theta+\&c.\}.$$

He ought to have found

$$a=\frac{G}{g}\{\sin^2\theta+0\cdot7504\sin^4\theta+0\cdot1566.\sin^6\theta+0\cdot0157.\sin^8\theta+0\cdot0009.\sin^{10}\theta+\&c.\}$$
$$+\frac{K_4}{g}\left\{\sin^4\theta+\frac{5}{8}\sin^6\theta+\left(\frac{7}{16}-\frac{5}{10.4}\right)\sin^8\theta+\left(\frac{189}{576}-\frac{79}{720}.\frac{5}{4}\right)\sin^{10}\theta+\&c.\right\}.$$

It is needless to observe that Laplace's numerical calculations of the heights of the tides in certain latitudes, and his inferences, as to the latitude where there is no tide, &c., fall to the ground.

This solution is applicable to a sea bounded on its north or south side.

(113.) If, using the more complete values of a that we have just found, we proceed to form the values of a''', b, and u, we find that u will contain a series of terms multiplied by the indeterminate K_4. We may determine K_4 so that, for a given value of θ, u shall $=0$; that is to say, so that, in a given latitude, the water shall have no north and south motion. We might therefore suppose an east and west barrier (following a parallel of latitude) to be erected in the sea, and the investigation would still apply. Thus then we have a complete solution for a sea which is bounded by a shore whose course is east and west.

(114.) The fluctuations of which we have last treated are those which Laplace has called "*les oscillations de la troisième espèce.*" They constitute the ordinary semidiurnal tide.

Separate effects of the Sun and Moon are to be combined by algebraical addition.

(115.) We have throughout this Section spoken of the luminary as if only the Sun or only the Moon were efficient in producing the tides. But the reader will easily understand that the same investigations, *mutatis mutandis*, apply to the moon as to the sun; and that, when the effect of each is found separately, their compound effect will be the algebraic sum of their separate effects. For our equations throughout comprehend only the first power of the terms depending on disturbing force, and the first power of the unknown p''' and the terms originating from it; and thus, if a term f_m, depending on the Moon's action, produces the term p_m, and a term f_s, depending on the Sun's action, produces the term p_s, then, by simple addition of the equations, the equation will be produced which shows that the combined terms f_m+f_s will produce p_m+p_s. This would not be true if the squares of terms of p''' entered, because the sum of the squares of p_m and p_s is not the same as the square of their sum: and so for higher powers.

(116.) With this we shall terminate our account of Laplace's Theory of the Tides; but, before closing this Section, we must call our reader's attention, as well to the important points of the investigation in general, as to the modification which we have thought desirable to introduce into Laplace's methods. We will first advert to the latter. Laplace has commenced with the equations of motion of fluids in their most general, and (we may be permitted to say) in their most repulsive form. Proceeding from these in a way which appears at first not easy to understand, but in which, nevertheless, the same operations may be traced as in the investigations of this Essay, he arrives at the equations of (87.), the assumptions of (89.), and the equations of (90.). From this point he proceeds by a method totally different from that which we have used. Partly for the generality of an investigation applying to all degrees of density of the sea, and partly (it would seem) for the sake of introducing his own favourite equation for the attraction of bodies nearly spherical, Laplace has embarrassed his process with investigations, nowhere fully explained, and sometimes only hinted at, applying to the different terms into which (for substitution in his own equation above alluded to) the disturbing forces and other quantities are to be resolved. In asserting that this is the most obscure of the investigations of the Mécanique Céleste, we trust that we may consider ourselves supported by the circumstance that no following mathematician has entered into Laplace's method for the tides, or has even verified his most remarkable results; although Laplace has frequently alluded to one of these (the evanescence of diurnal tide in height when the depth is uniform) in a way that shows that he considered it one of the happiest of his discoveries. We add that this investigation is *unnecessarily* obscure. Although the introduction of the density of the sea has apparently enabled Laplace to give greater generality to his symbols, it has given none to his final results. Of the latter class there are two, namely, the evanescence of the diurnal tide when the depth is uniform, and the numerical calculation of the semi-diurnal tide. The former is obtained by the methods of this Treatise; and, moreover, is obtained with the utmost generality as to density of fluid: for, if the depth is nowhere altered, the attraction is not altered, and therefore it is indifferent whether we treat the attraction of the fluid *per se*, or consider it included in the attraction of the rigid body. In the latter, Laplace has himself neglected the density of the water. We trust that these remarks will be thought sufficiently to explain our abandonment of Laplace's method, and our substitution for it of a method which is (we should hope) intelligible to almost every student of the differential calculus.

(117.) If now, putting from our thoughts the details of the investigation, we consider its general plan and objects, we must allow it to be one of the most splendid works of the greatest mathematician of the past age. To appreciate this, the reader must consider, first, the boldness of the writer who, having a clear understanding of the gross imperfection of the methods of his predecessors, had also the courage deliberately to take up the problem on grounds fundamentally correct (however it might be limited by suppositions afterwards introduced); secondly, the general difficulty of treating the motions of fluids; thirdly, the peculiar difficulty of treating the motions when the fluids cover an area which is not plane but convex; and, fourthly, the sagacity of perceiving that it was necessary to consider the Earth as a revolving body, and the skill of correctly introducing this consideration. The last point alone, in our opinion, gives a greater claim for reputation than the boasted explanation of the long inequality of Jupiter and Saturn.

Negative results of Laplace's theory.

(118.) If we look to the results of the theory, it will be found that they are rather of a negative than of a positive kind. They show that, without a far more complete knowledge of the form of the bottom of the sea than we can hope to possess, it will be impossible, even with more powerful mathematics, to calculate tides *à priori*. They show that the calculations founded on the equilibrium-theory cannot be good for anything. In proving that (with sea at least of a certain shallowness) the part of the equator next to the sun or moon would be a place of *low* water, they destroy all hope of using an equilibrium-theory, even as an approximation. In establishing the remarkable result as to the non-existence of diurnal tide in height when the depth is uniform, they show that no inference can be drawn from the mere magnitude of a force as to the magnitude of its effects.

Extension required to make the theory applicable to observations.

(119.) The results of this theory, however, would give us a knowledge of the physics of tides of no contemptible kind, if, upon any supposition whatever as to depth, we were able to introduce the horizontal limitation of the sea. This implies that we should be able to solve generally the equations of (87.) without the term $\Theta . \cos \overline{it + k\varpi}$. Such a solution, in a very limited case, is given by the indeterminateness of K_4 in (112.). We see not the smallest prospect of succeeding in this with the degree of generality required (that is, of expressing the solution by $A \cos it + B \sin it$, where A and B are the most general functions of θ and ϖ): we have, however, no hesitation in pointing out this as the subject which, in the present state of theory, is most especially worthy of the attention of the theoretical investigator of tides. It is principally in this respect that the theory (in other respects imperfect) of the next Section is superior to this. [The principle of introducing such limitations in general will be found in (291.) &c.] As it is, Laplace's theory fails totally in application, from the impossibility of introducing in it the consideration of the boundaries of the sea.

(120.) It is almost unnecessary to remark that this theory gives no assistance in explaining the peculiarities of river or channel tides: and it gives no idea whatever of the difference in the proportion of the effects produced by bodies (as the Sun and Moon) whose motions in right ascension are not precisely equal; a matter which we shall find to be very important.

(121.) After considering the negative nature of the results of his theory, and the degree in which any accurate conclusions must depend upon the precise knowledge and correct mathematical treatment of a number of circumstances which are wholly unknown, Laplace at last takes refuge in the assumption that all that we are certain of is, that the disturbances of the sea will be periodical as the forces that cause those disturbances, but that their times of maximum or minimum are not necessarily the same as the times of maximum or minimum of the forces, and that their coefficients are not necessarily in the same proportion as the forces which cause them, unless the periods of the forces are exactly the same. That is to say, if the forces acting in any given manner are represented by

$$A_{,} \cos (i_{,}t + B_{,}) + A_{,,} \cos (i_{,,}t + B_{,,}) + A_{,,,} \cos (i_{,,,}t + B_{,,,}) + \&c. ;$$

then the elevation of the tide will be represented by

$$C_{,} \cos (i_{,}t + B_{,} + E_{,}) + C_{,,} \cos (i_{,,}t + B_{,,} + E_{,,}) + C_{,,,} \cos (i_{,,,}t + B_{,,,} + E_{,,,}) + \&c.,$$

where the quantities $C_{,}$, $C_{,,}$, $C_{,,,}$, $E_{,}$, $E_{,,}$, $E_{,,,}$, can only be determined from experience. And that, in the case of a canal communicating with two tidal seas, any variation in the value of $i_{,}$ ($A_{,}$ and $B_{,}$ remaining unvaried) will be accompanied by a variation of $C_{,}$ and $E_{,}$. On this point the reader is referred to (312.).

(122.) We will terminate this Section by a brief demonstration of two of Laplace's supplementary propositions which are closely related to the subject before us.

The equilibrium of the sea is

(123.) The first is, that the equilibrium of the sea is stable (that is, if its relative position with the land is disturbed, it will have a tendency to return to its former position), if the density of the land is greater stable if its density is less than that of the earth.

than that of the sea; out is unstable if the density of the land is less than that of the sea. In fig. 4, suppose the land to be more dense than the water, and suppose that at any instant each is in the form of a sphere, the centre of the terrestrial sphere being at A, and the centre of the aqueous sphere being at B. The attraction of the whole may be found by conceiving the whole large sphere to be filled with matter of the same density as water, and conceiving the small sphere to have, in addition, the density equal to the excess of the density of earth over that of water. The attractions of these spheres will be directed to their respective centres. Thus, a particle p on the surface will be drawn by one of these attractions (that of the aqueous sphere) in the direction pB, and by the other (the excess of the sphere of earth over a similar sphere of water) in the direction pA. Representing these forces by pa and pb, their compound effect will be that of a force in the direction pc. It is evident that this force is not perpendicular to the surface at p (the normal being pB), but is inclined in such a direction that it tends to carry the particle p towards e. A similar result will be found for every particle at the surface, namely, that the force on the particle tends to carry it in that direction where the water is at present deficient; and tends, therefore, to restore the equality of distribution of the water.

The equilibrium of the sea is unstable if its density is greater than that of the earth.

(124.) But if the land is less dense than the water, then, in fig. 5, we may conceive the whole of the larger sphere to be occupied with matter of the same attractive power as water, but then we must suppose the small sphere to be occupied with a repulsive substance. The particle p will then be drawn by the complete aqueous sphere in the direction pB or pb, but will be repelled by the imaginary repulsive sphere in the direction pa. The whole force, therefore, on p will be represented by pc acting in the direction inclined to the normal pB on the side opposite to that in the last article, and therefore it will tend to carry the particles of water towards that side f where there is already a redundance, and, therefore, to cause the distribution of water to become more unequal than it is at present.

Investi tion of depen ence o preces upon tides.

(125.) The second supplementary proposition is, that the amount of precession, and its subordinate portions included under the general term *nutation*, are not affected by the tidal motions of the sea. To demonstrate this, we must refer to our Treatise on the FIGURE OF THE EARTH, section 9. It will there be seen that, in consequence of the action of the Sun and Moon upon the earth, supposed to be a solid, there is impressed upon the earth a tendency to revolve round an axis, which is in the plane of the equator; and that the result of the composition of this impressed motion of rotation with the motion of rotation about its polar axis is, that the real axis of rotation (a revolution about which will represent the real motion of every particle of the earth under the effect of the two rotations) will change its position in space, in that direction which exactly corresponds to precession (including nutation). The quantity, then, upon which the amount of precession will immediately depend, is the angular velocity which the action of the sun and moon tends to give round the equatorial axis of which we have spoken; and this angular velocity is represented by the fraction, whose numerator is the moment of all the impressed forces tending to produce rotation round that equatorial axis, and whose denominator is the moment of inertia of the earth about the same axis. If the water were united in one solid mass with the earth, we should, for the moment of impressed forces, merely consider the effect of the sun's and the moon's attraction upon the earth and upon the water. But, as the water is not rigidly connected with the earth, but has a fluctuating motion upon it, and acts upon the earth by a pressure which is modified as well by its elevation as by the circumstances of its motion, it is necessary to take into account the effect of the pressure of the water upon the earth, and the corresponding reaction of the earth upon the water. We must also consider that the same particles of water, in their tidal motion, always oscillate about nearly the same part of the earth.

Principle of the conservation of areas.

(126.) The most general way of considering this is the easiest. The particles of water act upon one another and upon the particles of earth, and the particles of earth act upon one another and upon the particles of water, either by the pressure of contact, or by attraction; and each of these forces produces an equal reaction upon the acting particle. Now there is a well known principle, called that of the *conservation of areas*, which is thus enunciated:—"The sum of the products of the mass of each particle into the area which it describes round a given axis is not altered by the mutual action of the particles." The demonstration of this (which is not given in our Treatise MECHANICS) may be shortly stated as follows. Let x, y be the co-ordinates of a particle m which is acted on by the accelerating forces X, Y; x', y' those of another particle m', which is acted on by the accelerating forces X′, Y′ (z being the axis of rotation); D the distance between these particles; and let F be the force, estimated as a pressure, with which these two particles attract each other. Then,

$$\frac{d^2 x}{dt^2}=\mathrm{X}+\frac{\mathrm{F}}{m}\cdot\frac{x'-x}{\mathrm{D}}$$

$$\frac{d^2 y}{dt^2}=\mathrm{Y}+\frac{\mathrm{F}}{m}\cdot\frac{y'-y}{\mathrm{D}}$$

$$\frac{d^2 x}{dt^2}=\mathrm{X}'+\frac{\mathrm{F}}{m'}\cdot\frac{x-x'}{\mathrm{D}}$$

$$\frac{d^2 y'}{dt^2}=\mathrm{Y}'+\frac{\mathrm{F}}{m'}\cdot\frac{y-y'}{\mathrm{D}}.$$

Therefore

$$m\left(x\frac{d^2 y}{dt^2}-y\frac{d^2 x}{dt^2}\right)=m(x\mathrm{Y}-y\mathrm{X})+\mathrm{F}\,\frac{xy'-yx'}{\mathrm{D}}.$$

But if r is put for the distance of m from the axis, and θ for the angle made by r with the plane of xz, $x = r\cos\theta$, $y = r\sin\theta$, and $x\frac{d^2y}{dt^2} - y\frac{d^2x}{dt^2} = \frac{d}{dt}\left(x\frac{dy}{dt} - y\frac{dx}{dt}\right) = \frac{d}{dt}\left(r^2\frac{d\theta}{dt}\right)$. Put A for the projection, on the plane xy, of double the area described by m round the axis in the unit of time; then $A = r^2\frac{d\theta}{dt}$: and this equation becomes

$$m\frac{dA}{dt} = m(xY - yX) + F.\frac{xy' - yx'}{D}.$$

Similarly for the other particle,

$$m'\frac{dA'}{dt} = m'(x'Y' - y'X') + F.\frac{x'y - y'x}{D}.$$

Adding these,

$$m\frac{dA}{dt} + m'\frac{dA'}{dt} = m(xY - yX) + m'(x'Y' - y'X');$$

or is the same as it would have been if there had been no mutual action of the particles. The same would be found to be true if there had been any number of particles. Then, integrating, we find that $mA + m'A' + \&c.$ is the same as if there had been no mutual action. It is, however, to be remarked, that if the ordinates x, y, x', y', &c. are sensibly altered by that mutual action, the products xY, yX, &c. are altered; and, therefore, in this indirect way the expressions for $m\frac{dA}{dt} + m\frac{dA'}{dt} + \&c.$ may be altered.

(127.) It follows from this, that the sum of the products of the mass of each particle of the earth and sea by the area which it describes round the equatorial axis is unaltered by the fluctuation of the sea (except so far as the surface is raised or depressed by that fluctuation, and the moment of the impressed forces is thereby increased or diminished; but this increase or diminution must be utterly insensible, and we shall give no further attention to it). Now, if the earth and sea were so entirely disconnected that one of them could revolve for any length of time with any velocity, increasing or diminishing in any manner, while the other could revolve with any other velocity changing in any other manner, we could pronounce nothing as to the effect of the fluctuations on precession. But the assumption on which we are to proceed is, that the tidal motion is not great, and is of an oscillatory kind. If, then, there were but a single sea upon the earth, and if in consequence of fluctuation this sea received a considerable velocity in the same direction in which the impressed forces tend to carry the earth, the rotation of the solid earth in that direction round the equatorial axis would thereby be *diminished* (in virtue of the *conservation of areas*). But as soon as that water came to a state of rest, the rotation of the earth round the equatorial axis would acquire the same value as if the water were rigidly connected with the earth; and when the water had a movement in the opposite direction, the earth's velocity of rotation round the equatorial axis would be *increased*. And this would be true whether or not the sea had had in the mean time, from the earth's diurnal revolution, a great motion parallel to z (for z does not enter into the formula), and whether or not the sea had been carried to the opposite side in respect of x or y (for the formula is perfectly general as regards changes of magnitude and sign of x and y). The same applies to any number of seas, of any forms. Thus, though the angular motion round the equatorial axis, and the consequent momentary precession, may be irregular, yet its irregularity will not extend beyond a single complete tidal oscillation; and the whole precession during one tide will be the same as if the water had been fixed.

(128.) The reader will perceive that, although through the greater part of this Section we have not taken into account the density of the water, we have taken it fully into account in these two supplementary propositions. And, in the last of them, we have departed from all hypotheses as to the symmetrical disposition of the water, and have supposed it to be distributed and bounded in any way whatever.

SECTION IV.—THEORY OF WAVES IN CANALS.

(129.) We have already stated (64.) that the Equilibrium-Theory of Tides, though curious in its relation to the history of the science, and valuable for the coincidence of the algebraic form of its results (under certain modifications) with those of more accurate theories, and with the laws deduced from observations, does not deserve the smallest attention as representing the state of the ocean at any time. We have also stated (65.) that Laplace's theory of the movement of the sea, supposing the globe completely covered by water, whose depth is uniform, or follows a very simple geographical law, though based upon sounder principles, has far too little regard to the actual state of the earth to serve for the explanation of the principal phænomena of tides. We now come to a third theory: that of the motion of the tidal waters, supposing them to run in the manner of ordinary waves in canals. It is evident that this theory will not apply to every part of the sea, and therefore it must, to a certain extent, be considered imperfect. Still it will apply strictly to many cases (to rivers without exception; and to arms of the sea where their breadth is smaller than their length, and where the irregularities of the coasts are not very remarkable), and it will apply without sensible modification to other cases of open seas, where the whole may be conceived divided into parallel canals in which the circumstances are nearly similar. For these reasons we are inclined to think that this mode of considering the subject, in the present imperfection of mathematics, deserves special notice among the various Theories of the Tides.

(130.) It is necessary for our present purpose to enter into a pretty general investigation of the Theory of Waves of water; and we shall therefore commence without any obvious reference to the subject of Tides.

(131.) We shall, for convenience, divide this Section into the following parts:

Subsection 1.—General explanation of waves; and general theory of waves, supposing the motion of the particles small.

Subsection 2.—Theory of waves in canals of uniform depth and uniform breadth, whether the waves be short or long, the motion of the particles being supposed small.

Subsection 3.—Theory of long waves in which the elevation of the water bears a sensible proportion to the depth of the canal.

Subsection 4.—Theory of waves when the water is acted on by horizontal and vertical forces, the motions of the particles being small; including also the theory of a single wave, and the theory of waves in canals of variable depth and variable breadth; with the introduction of the ideas of *free-wave* and *forced-wave*.

Subsection 5.—Method of introducing the limits of the canal in general; and application of the doctrine of *free-wave* and *forced-wave*.

Subsection 6.—Theory of waves, as affected by friction.

Subsection 7.—Theory of waves in water of three dimensions, or where the horizontal extent of the surface in two dimensions is taken into account.

Subsection 1.—*General Explanation of Waves, and general Theory of Waves, supposing the motion of the particles small.*

(132.) Without citing the explanations in other essays, it may be desirable here to call the reader's attention to the meaning of the term *wave*, and to the form of the mathematical expression which must be used to represent the motions of the particles of water in wave-motions. The same general ideas attach to the term *wave* or *undulation* in the sciences of Acoustics and Optics: and a clear conception of those ideas may be considered as one of the most important steps in the understanding of many important physical sciences.

A wave in continuous motion does not imply that the water is continuously moving in the same direction.

(133.) In watching the waves of the sea (we allude not to the breaking of the surf, which will be distinctly considered hereafter), the reader may perhaps have imagined that, in each wave, a quantity of water, equal in bulk to that wave, was advancing towards the shore. A very little attention, however, would show that this notion is incorrect. A cork, or a particle of foam, floating on the water, is not carried towards the shore; if watched narrowly, it will be found that it moves towards the shore while the crest of each wave is under it, and from the shore while it is in the hollow of each wave, but these motions are scarcely greater than its vertical motions, and the advance and the regress sensibly balance each other.

It is only the motion of a shape.

(134.) Thus it will appear, as a visible fact, that the continued motion of a wave in one direction is not a continued motion of the water in that direction, but may be described as a continued motion of a *shape*, or of an *arrangement of the particles of the water*. It is necessary now to show that a very small reciprocating motion of each particle of water is sufficient to account for unlimited motion of the *wave* or *shape* continued constantly in one direction.

(135.) In figure 6, suppose that ABCDEFG represents the outline of a succession of waves at one instant of time, *abcdefg* the outline at a second instant; it is required to show how the waves can have advanced from the position ABCDEFG to *abcdefg* by a small oscillating motion of each particle of water.

Explan tion of tion of wave b oscilla motion the pa ticles.

(136.) Draw vertical lines from the surface to the bottom of the water; conceive that all the particles in each line are subject to motion in the direction represented by the small arrows in the figure; that is, that all the particles below the crest of the wave are moving forwards; that all the particles below the hollow of the wave are moving backwards; and that all below the midway-points (A, C, E, G,) are for the moment stationary. And suppose that the velocity of the horizontal motion of the particles in vertical lines intermediate to those drawn in the figure is intermediate to the velocities of the particles in the lines drawn in the figure. This supposition will account for the motion of the wave or *shape*.

(137.) For, take points B_0, B_1 near to B: C_0, C_1 near to C, &c.: draw lines from them to the bottom, and consider the horizontal motion of the particles in those lines. B_0 and B_1 are both between the point of principal backward motion and the point of rest; therefore the particles below B_0 and those below B_1 will be moving backwards, and with nearly the same speed: and therefore the intermediate surface at B will not be sensibly elevated or depressed, inasmuch as the vertical boundaries $B_0\,B_0'$ and $B_1\,B_1'$ of the included column of water will, after a short time, be at the same distance from each other as at present. But the particles in the line $C_0\,C_0'$ are between a point of rest and a point of backward motion, and therefore are moving backwards; those in the line $C_1\,C_1'$ are between a point of rest and a point of forward motion, and therefore are moving forwards; consequently the vertical boundaries, $C_0\,C_0'$, $C_1\,C_1'$, of the included column are separating more widely apart, and therefore the surface at C will drop, and will, after a short time, be found depressed to *c*. In like manner it will be found that in both the lines $D_0\,D_0'$ and $D_1\,D_1'$ the particles are moving forward with nearly the same velocity, and therefore in the intermediate part at D the elevation of the surface is not sensibly altered. But in $E_0\,E_0'$ the particles are moving forward, and in $E_1\,E_1'$ they are moving backward; the horizontal space between these boundaries is therefore diminished, and therefore the surface of the water between them is raised; and it will therefore, after a short time, be found at *e* instead of E. Pursuing this reasoning it will be evident that the continued horizontal motion of the wave or *shape* forwards is entirely accounted for by the rising of some portions of the surface and the falling of others, and that these risings and fallings may be considered as the effect of small horizontal motions of the particles of the water, some forwards and others backwards.

(138.) And as, in the progress of the waves, the same particles are alternately on the crest and in the hollow of the wave, every particle will be alternately moving forwards and backwards, and alternately upwards and downwards; the wave meanwhile will be advancing continually in the same direction.

(139.) The reader must consider the above as merely a general *geometrical* explanation of the motion of a wave by means of oscillating motions of every particle of the water. Whether such motions are consistent with the various forces acting upon water (which forces themselves depend in part upon the motions of the particles) will shortly be a most important subject of inquiry. But from the tenor of this explanation, we may at once collect what must be the form of the mathematical expressions which will be necessary to represent the motions of the particles. We shall call the horizontal ordinate of any particle in its position of rest, measured in the direction of the canal's length from some fixed point, x: and the vertical ordinate of any particle in its position of rest, measured upwards from some horizontal plane (which, when the depth is uniform, may be the bottom of the water) y.

(140.) Now, first, it appears from our explanation that each particle is disturbed in the horizontal as well as in the vertical direction. Consequently, to represent the position of any particle at any time, we must use for co-ordinates

$$x'=x+\mathrm{X}$$

$$y'=y+\mathrm{Y},$$

where both X and Y depend on, or are functions of, x, y, and t (t being used to express the time, as measured from some arbitrary epoch.)

Algebraic characteristic of a wave.

(141.) Secondly. The characteristic of a wave is this: that though, at any one instant, different particles are displaced in different ways; yet, the state of any particle in advance (that is, a particle for which x is large) will be, at some future time, the same as the state of a particle in arrear (that is, a particle for which x is small) is now, provided we wait during a time proportioned to the interval of space between these two particles. In other words: supposing the velocity of the wave to be v, so that in the time t' it will move through $v\,t'$: then the characteristic of a wave is, that the particle whose ordinate is $x+vt'$ will have the same disturbance at the time $t+t'$, which the particle whose ordinate is x has at the time t. Mathematically expressed, putting $\phi(x,t)$ for the disturbance at the time t of a particle whose ordinate was x,

$$\phi(x,t)=\phi(\overline{x+vt'},\ \overline{t+t'}):$$

expanding this latter to the first power of t',

$$\frac{d.\phi(x,t)}{dx}vt'+\frac{d.\phi(x,t)}{dt}t'=0:$$

a well known equation, whose solution is

$$\phi(x,t)=\chi(vt-x),$$

χ being any arbitrary function. As v is not known, it will be equally convenient to put this under the form

$$\chi(nt-mx)$$

where n and m are constants: the function χ being still arbitrary (that is, capable of adaptation to any physical assumption) though not precisely the same as in the former expression. If we suppose the horizontal movements of the particles in different points of the same vertical to be different, we may express that supposition by multiplying this expression by a function of y, which will give

$$\mathrm{X} \text{ or } \phi(x,t)=\mathrm{F}(y)\times\chi(nt-mx).$$

And if we suppose that the horizontal movements of the particles in different points of the same vertical are not simultaneous; for instance, that their times of rest or their times of greatest motion do not all occur at the same instant; we may use the expression

$$\mathrm{X}=\mathrm{F}(y)\times\chi(nt-mx-\mathrm{Q}),$$

where Q depends on y only.

Characteristic when the motion of particles is oscillatory.

(142.) Thirdly. The motion of each particle of water was supposed to be *reciprocating* or *oscillatory*. There is no kind of expression so convenient for representing oscillatory motion as one depending on sines or cosines. And by combination of several terms of that kind, any kind of oscillation may be represented. Thus, the formula

$$\cos(nt-mx)$$

would represent a regular oscillation going through all its changes while nt increased by 2π, or while t increased by $\frac{2\pi}{n}$: but the following formulæ

$$\cos(nt-mx)+a\cos(2nt-m'x)$$

$$\cos(nt-mx)+a.\cos(2nt-m'x)+b.\cos(3nt-m''x)$$

would represent regular oscillations of a different kind, but still going through all their changes while t increased by $\frac{2\pi}{n}$. It will even be seen hereafter that, by proper management of these terms, we may investigate the motions of a *discontinuous* wave, that is where a single wave, and no more, passes along a canal. For these reasons, we shall always suppose the function χ to have the form of a series of sines or cosines of multiples of $nt-mx$. But as each of these terms will be treated separately in the same manner, we shall omit all but the first (for convenience only), and shall therefore assume

$$X=F(y).\cos(nt-mx-Q).$$

The form of Y, as will appear in the investigation, will necessarily follow from that of X.

Characteristic when the form of the wave changes.

(143.) Fourthly. In some very important cases, we shall find it necessary to depart from our original simple suppositions. Circumstances may be conceived, in which, without at all losing the character of a single determinate series of waves, the elevation of each wave alters as it proceeds; and the linear interval between the crest of one wave and the crest of the next wave alters, (the interval of time remaining the same as before,) or the velocity of the wave alters. Thus, in figure 7, the wave, which while at ABC was long and flat, may at IKL become short and steep. This case will be fully represented by introducing a variable coefficient depending on x, and by conceiving that the factor m, or $\frac{n}{v}$, by which the periodic function depends on x, is itself a function of x, and that, instead of a product, an integral is to be used. Thus we shall have

$$X=F(y).G(x).\cos(nt-\textstyle\int_x m).$$

We shall now proceed with that part of the investigation which depends on the properties of fluids.

(144.) In figure 8, let *o*O represent the bottom of a canal of variable depth: *abc* the surface of the water in a state of rest, ABC the surface at a certain instant of time when in wave-motion: and suppose that the very narrow column of water, which when the whole was at rest had the form *oc*, has at this instant the form OC. Suppose the column *oc* divided into a very great number of small parts by horizontal planes, and let *ps* be one of these parts, and PS the corresponding part of the column OC in its displaced state at the instant under consideration. Let the coordinates of the point *o* at the bottom be x and η: the vertical coordinate of the surface *abc* be k: the coordinates of p be x and y: and suppose $pq=h$, $pr=l$. And put X for the horizontal displacement, and Y for the vertical displacement, of the particle whose coordinates are x and y, at the instant under consideration. Let Ξ be the value of X at the bottom, and K the value of Y at the top. Then, considering the disturbance so small that all quantities beyond the first order may be omitted,

The horizontal ordinate of $P=x+X$,

The horizontal ordinate of $Q=x+h+X+\frac{dX}{dx}h$,

therefore the horizontal distance between P and Q $=h\times\left(1+\frac{dX}{dx}\right)$ nearly.

And the vertical ordinate of $P=y+Y$,

The vertical ordinate of $R=y+l+Y+\frac{dY}{dy}l$,

therefore the vertical distance between P and R $=l\times\left(1+\frac{dY}{dy}\right)$ nearly.

Investigation of equation of continuity.

(145.) Now, conceiving that the water, which occupied the volume *ps* without any vacant space, does now occupy the volume PS without any vacant space, or remains *continuous*, it is evident that we must have

$$\text{area } ps=\text{area PS}.$$

But, as in (72.), the area PS, considered as a rhomboid, $=\text{PQ}\times\text{PR}\times\sin\text{RPQ}$,

$=\text{PQ}\times\text{PR}\times$ cosine (inclination of PQ to horizontal line + inclination of PR to vertical)

$=$(PQ × cos incl. PQ to horiz. line) × (PR × cos incl. PR to vertic. line) × (1 − tan incl. PQ . tan incl. PR)

$=$(hor. dist. between P and Q) × (vert. dist. between P and R) × (1 − tan incl. PQ . tan incl. PR).

Now the inclination of PQ to the horizontal line is small; and that of PR to the vertical is small: therefore the product of their tangents is exceedingly small, and may be neglected. Hence we obtain

area PS = (hor. dist. between P and Q) × (vert. dist. between P and R)

$$=h\times\left(1+\frac{dX}{dx}\right)\times l\times\left(1+\frac{dY}{dy}\right)$$

$$=hl\times\left(1+\frac{dX}{dx}+\frac{dY}{dy}\right)\text{ nearly.}$$

Making this equal to area $ps=hl$, we obtain

$$0=\frac{dX}{dx}+\frac{dY}{dy},$$

or

$$Y=-\int_y \frac{dX}{dx}+\text{a function of } x.$$

As there is a fixed boundary to the water at the bottom, we must commence our integration there. Now it is evident that at the bottom the value of Y is $\Xi\times\frac{d\eta}{dx}$, inasmuch as the lowest particles of the water are pushed through the horizontal space Ξ in contact with the sloping bottom whose vertical ordinate is η, and the tangent of whose inclination to the horizon is, therefore, $\frac{d\eta}{dx}$. Thus we have

Equation of continuity.

$$Y=\Xi.\frac{d\eta}{dx}-\int_y \frac{dX}{dx} \text{ (from } y=\eta \text{ to } y).$$

This is the equation of continuity.

(146.) Now let us consider the relation, between the forces which act on the different points of the water, and the motion of the water. Continue the horizontal plane pq to TV, and from T and V draw the vertical lines TW, VX, to the disturbed surface. The points W and X do not coincide with B and C, but in regard to the accuracy of any expression depending merely on the wave-disturbance they may be used indifferently; because WB and XC depend upon the extent of disturbance, and the slope of WB and XC also depend on the extent of disturbance, so that the difference of elevations of W and B, or of X and C, will depend on the square of the disturbance. But the difference of elevations of W and X (which is the difference that we shall shortly use) depends on the extent of disturbance; and, therefore, when the disturbance is made very small, it is a much greater quantity than the difference of elevations of W and B, which depends on the square of the disturbance. And this is entirely independent of the length of the wave. Thus, in a wave whose length from crest to crest is many feet, the whole value of WB may be an inch: by diminishing the violence of the motion, or making the wave flatter, while its length remains the same, WB may be diminished to a tenth of an inch, and then the difference of elevation of W and B will be a hundredth part of what it was before, while that of W and X will be a tenth part of what it was before. Thus, when the motion of the particles is small, instead of using the value of K corresponding to the point W, we may use that which corresponds to the point B: and instead of using the difference between the values of K for W and X, we may use the difference between the values of K corresponding to B and C.

Investigation of the equation of equal pressure.

(147.) Now let p be the pressure at any point in the line PW, estimated by the velocity which that pressure acting on the surface 1 would produce in the volume of water 1, by acting during the time 1. Then p will be a function of x, y, and t. Let g' be the force of gravity, estimated by the velocity which it will produce by its action during the time 1: for reasons which will hereafter appear we shall consider g' as varying from one point of the earth's surface to another, or as being a function of x. Then the pressure at the point whose elevation is y' is p; that at the point whose elevation is $y'+\delta y'$ is $p+\frac{dp}{dy'}\delta y'$: the excess of the upper pressure above the lower is $\frac{dp}{dy'}\delta y'$: and this excess, acting on the column whose length is $\delta y'$, will tend to urge it downwards with an acceleration represented by $\frac{dp}{dy'}$. Adding to this the effect of gravity, we shall have the whole acceleration downwards $=\frac{dp}{dy'}+g'$. Therefore

$$\frac{d^2y'}{dt^2}=-\frac{dp}{dy'}-g'.$$

But $y'=y+Y$, therefore $\frac{d^2y'}{dt^2}=\frac{d^2Y}{dt^2}$ (as y does not depend on t). Consequently

$$\frac{dp}{dy'}=-g'-\frac{d^2Y}{dt^2}, \text{ and } p=\int_{y'}\left(-g'-\frac{d^2Y}{dt^2}\right).$$

Performing the integration from y to $k+K$, ($k+K$ being the value of y' at the surface of the water,) so that the pressure at the surface is zero,

$$p=g'(k+K-y)+\int_{y'}\frac{d^2Y}{dt^2} \text{ (from } y'=y \text{ to } y'=k+K).$$

But, as $\frac{d^2Y}{dt^2}$ is itself a small quantity depending on the motion of the particles, we shall incur no sensible error by integrating with respect to y instead of y', and by taking for superior limit k instead of $k+K$. Thus we obtain for the pressure at T

$$p=+g'(k+K-y)+\int_y \frac{d^2Y}{dt^2}\,(y \text{ to } k).$$

(148.) The particle at V corresponds to a point whose ordinate in the state of rest did not sensibly differ from $x+h$, and the pressure at V is, therefore, $p+\frac{dp}{dx}h$ nearly.

(149.) These pressures have been found from consideration of the motions of the particles of water in a vertical direction, and are therefore vertical pressures. Now the peculiar property of fluids is, that the pressure is equal in all directions, or that the expressions which we have found for the vertical pressures at T and V represent also the horizontal pressures at those points. (On this subject the reader is referred to article 75.) Thus we have

Horizontal pressure at T tending to push TV forwards $=p$,

Horizontal pressure at V tending to push TV backwards $=p+\frac{dp}{dx}h$.

Difference, tending to push TV forwards $=-\frac{dp}{dx}h$.

The length of the column TV on which it acts is nearly h: therefore the pressure tends to urge it forwards with an acceleration represented by $-\frac{dp}{dx}$. If, besides, any force depending on extraneous causes is acting, which would produce an acceleration represented by F, the whole acceleration will be $F-\frac{dp}{dx}$. Thus we have

$$\frac{d^2(x+X)}{dt^2}=F-\frac{dp}{dx}.$$

But x does not depend on t, therefore $\frac{d^2(x+X)}{dt^2}=\frac{d^2X}{dt^2}$. And, putting for p its value, we finally obtain this equation,

Equation of equal pressure.

$$\frac{d^2X}{dt^2}=F+\frac{d}{dx}\left\{-g'(k+K-y)-\int_y \frac{d^2Y}{dt^2}\,(y \text{ to } k)\right\}.$$

This may be called the equation of equal pressure.

This equation, in conjunction with the equation

$$Y=\Xi.\frac{d\eta}{dx}-\int_y \frac{dX}{dx}\,(\eta \text{ to } y),$$

contains the whole theory of the motion of fluids in canals, of uniform breadth, but of uniform or variable depth, the motion being supposed to be entirely longitudinal and vertical.

Equation of equal pressure when gravity is uniform.

(150.) If gravity be considered uniform, and $=g$, the term $\frac{d}{dx}\{-g'(k+K-y)\}$ becomes $\frac{d}{dx}(-gk+gy-gK)$ $=\frac{d}{dx}(-gK)$: and the equation of equal pressure becomes

$$\frac{d^2X}{dt^2}=F+\frac{d}{dx}\left\{-gK-\int_y \frac{d^2Y}{dt^2}\,(y \text{ to } k)\right\}.$$

Equation of continuity when the depth is uniform.

If the depth of the canal be uniform, $\frac{d\eta}{dx}=0$, and the equation of continuity, taking $\eta=0$, or assuming y to be measured from the bottom, becomes

$$Y=-\int_y \frac{dX}{dx}\,(0 \text{ to } y).$$

(151.) In the treatment of these equations, different methods must be used, according to the demands of the problem. If the nature of the motion in the direction of x be assumed; that is, if the expression for X be known, and if it be required to find what force is necessary to maintain the fluid in that state of motion; then we must, from the given expression for X, find the expression for Y by the equation of continuity; and, substituting both in the equation of equal pressure, we shall obtain F. But if F be given, and X and Y be required, we can only eliminate Y by means of the equation of continuity, and then solve the equation for X by methods depending on the form of the resulting equation.

(152.) If there be no motion of the particles, $0=\mathrm{F}-\frac{d}{dx}(g'.\overline{k+\mathrm{K}-y})$; or, if gravity be constant, $0=\mathrm{F}-g\frac{d\mathrm{K}}{dx}$.

Equations limited to oscillatory motion.

(153.) Hitherto we have not, in the investigation, limited ourselves in any way to the case of oscillating motion of the particles: the equations are, in fact, perfectly general as to the kind of longitudinal and vertical motion, and require only that the motion be small in extent. We shall now assume that the motion is oscillating; and, for the reason mentioned in (142.), we shall confine the expression for X or Y to a single term represented by a cosine or sine. Now suppose X to be represented by A cos (nt—B), where A and B are any functions whatever of x and y. (This is the most general form that can be assumed: it does not even imply that the form or magnitude of the waves is uniform, or that the motions of particles, originally in the same vertical column, are constantly in the same direction.) Then $\frac{d^2\mathrm{X}}{dt^2}=-n^2\mathrm{A}\cos(nt-\mathrm{B})=-n^2\mathrm{X}$. And as, in consequence of the equation of continuity, Y will necessarily depend on the sines or the cosines of the same angle $nt-\mathrm{B}$, we shall also have $\frac{d^2\mathrm{Y}}{dt^2}=-n^2\mathrm{Y}$. Thus the equation of equal pressure becomes

$$-n^2\mathrm{X}=\mathrm{F}+\frac{d}{dx}\{-g'(k+\mathrm{K}-y)+n^2\textstyle\int_y\mathrm{Y}\ (y\text{ to }k)\};$$

or, if gravity is considered as uniform,

$$-n^2\mathrm{X}=\mathrm{F}+\frac{d}{dx}\{-g\mathrm{K}+n^2\textstyle\int_y\mathrm{Y}\ (y\text{ to }k)\}.$$

We shall now proceed with some applications of these equations.

(154.) Problem.—To examine whether it is possible that a system of waves, depending upon oscillatory motion of the particles of water, can move along a canal of uniform breadth, but of variable depth: gravity being supposed uniform, and no other force being supposed to act.

Investigation of the possibility of unbroken waves when the depth is variable.

(155.) The equations to be satisfied are

$$\mathrm{Y}=\Xi.\frac{d\eta}{dx}-\int_y\frac{d\mathrm{X}}{dx}(\eta\text{ to }y)$$

$$-n^2\mathrm{X}=\frac{d}{dx}\{-g\mathrm{K}+n^2\textstyle\int_y\mathrm{Y}\ (y\text{ to }k)\}.$$

Differentiating the first with respect to y and to x,

$$\frac{d\mathrm{Y}}{dy}=-\frac{d\mathrm{X}}{dx}$$

$$\frac{d^2\mathrm{Y}}{dy\,dx}=-\frac{d^2\mathrm{X}}{dx^2}.$$

The second equation, observing that the limits of integration of $\int_y\mathrm{Y}$ are independent of x, may be put under this form,

$$-n^2\mathrm{X}=-g.\frac{d\mathrm{K}}{dx}-n^2\int_y\frac{d\mathrm{Y}}{dx}(k\text{ to }y).$$

Differentiating with respect to y,

$$-n^2\frac{d\mathrm{X}}{dy}=-n^2\frac{d\mathrm{Y}}{dx},\quad\text{or}\ \frac{d\mathrm{X}}{dy}=\frac{d\mathrm{Y}}{dx}.$$

Differentiating again with respect to y,

$$\frac{d^2\mathrm{X}}{dy^2}=\frac{d^2\mathrm{Y}}{dx\,dy}.$$

Eliminating $\frac{d^2\mathrm{Y}}{dx\,dy}$ by means of the former equation,

$$\frac{d^2\mathrm{X}}{dy^2}+\frac{d^2\mathrm{X}}{dx^2}=0,$$

the general solution of which equation is

$$\mathrm{X}=\phi(y+x\sqrt{-1})+\psi(y-x\sqrt{-1}),$$

where ϕ and ψ express functions chosen to satisfy any conditions required by the circumstances of the problem.

If, instead of ϕ and ψ, we use two other functions χ and ω, we may put the solution under this form,

$$X=\{\chi(y+x\sqrt{-1})+\chi(y-x\sqrt{-1})\}+\frac{1}{\sqrt{-1}}\{\omega(y+x\sqrt{-1})-\omega(y-x\sqrt{-1})\}$$

Sect. Theor Wave

the whole of which is real, whatever be the form of the functions χ and ω, provided that they contain, in their form, nothing imaginary.

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(156.) But the expression just found is the solution of the *derived* equation. We have now to ascertain whether it will satisfy the *original* equations. For convenience we will confine our substitution to a single term (as the result produced by another term will be easily inferred from its result), and will make

$$X=v'(y+x\sqrt{-1}),$$

conceiving v' to be the derived function of some function v. Then

$$\frac{dX}{dx}=\sqrt{-1}.v''(y+x\sqrt{-1})$$

$$\int_y\frac{dX}{dx}=\sqrt{-1}.v'(y+x\sqrt{-1})$$

therefore $-\int_y\frac{dX}{dx}$ from η to y is $\quad\sqrt{-1}\,v'(\eta+x\sqrt{-1})-\sqrt{-1}.v'(y+x\sqrt{-1})$;

Also Ξ, or the value of X when $y=\eta$, $\quad=v'(\eta+x\sqrt{-1})$,

therefore $\quad\Xi\frac{d\eta}{dx}=v'(\eta+x\sqrt{-1})\frac{d\eta}{dx}.$

Hence

$$Y=\Xi\frac{d\eta}{dx}-\int_y\frac{dX}{dx}(\eta\text{ to }y)=v'(\eta+x\sqrt{-1})\left(\frac{d\eta}{dx}+\sqrt{-1}\right)-\sqrt{-1}.v'(y+x\sqrt{-1})$$

$$=\frac{d}{dx}.v(\eta+x\sqrt{-1})-\sqrt{-1}.v'(y+x\sqrt{-1}).$$

And K, or the value of Y when $y=k$, $\quad=\frac{d}{dx}.v(\eta+x\sqrt{-1})-\sqrt{-1}.v'(k+x\sqrt{-1})$;

therefore $\quad g\frac{dK}{dx}=g\frac{d^2}{dx^2}v(\eta+x\sqrt{-1})+g.v''(k+x\sqrt{-1}).$

And $\quad\frac{dY}{dx}=\frac{d^2}{dx^2}v(\eta+x\sqrt{-1})+v''(y+x\sqrt{-1})$;

therefore $\int_y\frac{dY}{dx}(y\text{ to }k)$ is $\quad(k-y)\frac{d^2}{dx^2}v(\eta+x\sqrt{-1})+v'(k+x\sqrt{-1})-v'(y+x\sqrt{-1}).$

Substituting these in the equation $\quad-n^2X=-g\frac{dK}{dx}+n^2\int_y\frac{dY}{dx}(y\text{ to }k)$,

$$-n^2.v'(y+x\sqrt{-1})=-g\frac{d^2}{dx^2}v(\eta+x\sqrt{-1})-gv''(k+x\sqrt{-1})+n^2(k-y)\frac{d^2}{dx^2}v(\eta+x\sqrt{-1})$$
$$+n^2v'(k+x\sqrt{-1})-n^2v'(y+x\sqrt{-1}).$$

Removing the terms which mutually destroy each other, and conceiving the same substitution to be made for a term $v'(y-x\sqrt{-1})$, we shall have this equation,

$$0=(n^2k-n^2y-g)\frac{d^2}{dx^2}\{v(\eta+x\sqrt{-1})+v(\eta-x\sqrt{-1})\}-g\{v''(k+x\sqrt{-1})+v''(k-x\sqrt{-1})\}$$
$$+n^2\{v'(k+x\sqrt{-1})+v'(k-x\sqrt{-1})\}$$

(157.) It is evident, from the form of the multipliers, and the perfect independence of x and y, that this equation implies the existence of the separate equations.

$$0=\frac{d^2}{dx^2}\left\{v(\eta+x\sqrt{-1})+v(\eta-x\sqrt{-1})\right\}$$

$$0=-g\{v''(k+x\sqrt{-1})+v''(k-x\sqrt{-1})\}+n^2\{v'(k+x\sqrt{-1})+v'(k-x\sqrt{-1})\}$$

When the depth is variable, that is, when η is a function of x, it does not appear possible to satisfy the first of these equations by any form of v. It would appear, therefore, that when the depth is variable, it is impossible that there can be a series of waves which consist of oscillatory motion of the particles, and which satisfy the two equations of continuity and of equal pressure.

(158.) The following physical interpretation of this mathematical result appears to be correct, and is worthy of attention. It appears that, if the water is moving in the manner of waves, one at least of the two conditions (continuity and equal pressure) must fail. While the continuity holds, the equal pressure will exist, from the nature of the fluid. Therefore the continuity must cease, or the water must become *broken*. This appears to be the explanation of the broken water which is usually seen upon the edge of a shoal or a ledge of rocks, although the whole is covered, perhaps deeply, by the water. We shall advert again to this subject.

Waves consisting of oscillatory motion not possible when the depth is not uniform.

(159.) When the depth is uniform, or $\eta=0$, there is no difficulty in satisfying the equation. For instance, if $v(\theta)=\varepsilon^{m\theta}-\varepsilon^{-m\theta}$, the expression $v\,(y+x\sqrt{-1})+v\,(y-x\sqrt{-1})$ becomes $2\,(\varepsilon^{my}-\varepsilon^{-my})\,.\cos mx$, which when $y=0$ is always$=0$. Any other form of $v\,(\theta)$ expressed by odd powers only of θ would do equally well.

Subsection 2.—Investigation of the Motion of Waves in a Canal of uniform Depth, the Motions being small.

(160.) We shall assume (as a hypothesis to be proved or disproved by substitution in the equations) that the motion of the waves is uniform, and that all the motions of the particles, horizontal and vertical, are oscillatory; but we shall not, in the first instance, assume that the motions of all the particles in the same vertical line are of the same kind at the same instant. This will be expressed by assuming

$$X=P.\cos\,(nt-mx-Q)$$

where m is constant and P and Q may be functions of y.

Expanding the cosine, and making $P.\cos Q=R$, $P.\sin Q=S$, this becomes

$$X=R.\cos\,(nt-mx)+S.\sin\,(nt-mx).$$

(161.) Now, as we have found (155.), $\dfrac{d^2X}{dy^2}+\dfrac{d^2X}{dx^2}=0$: which in the present instance becomes

$$\left(\frac{d^2R}{dy^2}-m^2R\right)\cos\,(nt-mx)+\left(\frac{d^2S}{dy^2}-m^2S\right)\sin\,(nt-mx)=0.$$

Therefore $$\frac{d^2R}{dy^2}-m^2R=0,\qquad \frac{d^2S}{dy^2}-m^2S=0;$$

whence $$R=C.\varepsilon^{my}+D.\varepsilon^{-my},\qquad S=C'.\varepsilon^{my}+D'.\varepsilon^{-my},$$

and $$X=(C.\varepsilon^{my}+D.\varepsilon^{-my})\cos\,(nt-mx)+(C'.\varepsilon^{my}+D'.\varepsilon^{-my})\sin\,(nt-mx).$$

And as $Y=-\int_y\dfrac{dX}{dx}$ (0 to y), we easily find

$$Y=-(C\varepsilon^{my}-D\varepsilon^{-my}-C+D)\sin\,(nt-mx)+(C'.\varepsilon^{my}-D'.\varepsilon^{-my}-C'+D')\cos\,(nt-mx)$$

$$K=-(C\varepsilon^{mk}-D\varepsilon^{-mk}-C+D)\sin\,(nt-mx)+(C'.\varepsilon^{mk}-D'.\varepsilon^{-mk}-C'+D')\cos\,(nt-mx)$$

$$\frac{dY}{dx}=+m\,(C\varepsilon^{my}-D\varepsilon^{-my}-C+D)\cos\,(nt-mx)+m\,(C'.\varepsilon^{my}-D'.\varepsilon^{-my}-C'+D')\sin\,(nt-mx)$$

$$\int_y\frac{dY}{dx}\,(y\text{ to }k)=$$

$$-\{C\varepsilon^{my}+D\varepsilon^{-my}-C\varepsilon^{mk}-D\varepsilon^{-mk}+m.\overline{y-k}\,.\,\overline{-C+D}\}\cos\,(nt-mx)$$
$$-\{C'.\varepsilon^{my}+D'.\varepsilon^{-my}-C'.\varepsilon^{mk}-D'.\varepsilon^{-mk}+m.\overline{y-k}\,.\,\overline{-C'+D'}\}\sin\,(nt-mx)$$

Substituting in the equation $-n^2X=-g\dfrac{dK}{dx}+n^2\displaystyle\int_y\dfrac{dY}{dx}\,(y\text{ to }k)$

$$-n^2\,(C\varepsilon^{my}+D\varepsilon^{-my})\cos\,(nt-mx)-n^2\,(C'.\varepsilon^{my}+D'.\varepsilon^{-my})\sin\,(nt-mx)=$$
$$-mg\,(C\varepsilon^{mk}-D\varepsilon^{-mk}-C+D)\cos\,(nt-mx)-mg\,(C'.\varepsilon^{mk}-D'\varepsilon^{-mk}-C'+D')\sin\,(nt-mx)$$
$$-n^2\,\{C\varepsilon^{my}+D\varepsilon^{-my}-C\varepsilon^{mk}-D\varepsilon^{-mk}+m.\overline{y-k}.\overline{-C+D}\}\cos\,(nt-mx)$$
$$-n^2\,\{C'.\varepsilon^{my}+D'.\varepsilon^{-my}-C'.\varepsilon^{mk}-D'.\varepsilon^{-mk}+m.\overline{y-k}.\overline{-C'+D'}\}\sin\,(nt-mx)$$

Removing the terms which destroy each other, equating separately the coefficients of cos $(nt-mx)$ and of sin $(nt-mx)$, and observing that y is entirely independent of k, we obtain in the first place

$$-C+D=0 \qquad -C'+D'=0: \qquad \text{or } D=C, \qquad D'=C'.$$

Substituting these values of D and D′ in the other equations, they become

$$-mg\,C\,(\varepsilon^{mk}-\varepsilon^{-mk})+n^2\,C.\,(\varepsilon^{mk}+\varepsilon^{-mk})=0$$
$$-mg\,C'\,(\varepsilon^{mk}-\varepsilon^{-mk})+n^2\,C'\,(\varepsilon^{mk}+\varepsilon^{-mk})=0.$$

These equations leave C and C′ indeterminate; and they agree in giving the following relation between m and n,

$$n^2=mg.\,\frac{\varepsilon^{mk}-\varepsilon^{-mk}}{\varepsilon^{mk}+\varepsilon^{-mk}}.$$

Then, substituting in R and S the values of D and D′,

$$X=(\varepsilon^{my}+\varepsilon^{-my}).\{C\cos(nt-mx)+C'\sin(nt-mx)\};$$

Expressions for displacement of particles in wave-motion when the depth is uniform.

or if $A=\sqrt{C^2+C'^2}$, $\tan B=\frac{C'}{C}$; then $C=A\cos B$, $C'=A\sin B$, and the expression becomes

$$X=A.\,(\varepsilon^{my}+\varepsilon^{-my}).\,\cos(nt-mx-B)$$

where A and B are independent of x and y, and m depends upon n by the equation above. From this we easily find

$$Y=-A.\,(\varepsilon^{my}-\varepsilon^{-my}).\,\sin(nt-mx-B).$$

(162.) From these expressions it appears, as B is constant, that the mathematical results compel us to admit (what we did not at first assume) that the motion of all the particles originally in the same vertical line is, at any instant, of the same kind, although the extent of the motion of the different particles is very different. In future we shall generally omit B from the expression, as the same effect will be produced in the value of the expression by altering the origin of the time as by retaining B.

Explanation of terms.

(163.) It will be convenient to explain here a few terms which will hereafter be occasionally used.

Phase.

(164.) The angle $nt-mx-B$, or $nt-mx$, upon which the expressions for X and Y depend, is called the *phase* of the wave. It is to be considered as an angle, or rather as part of a circle (in the sense in which trigonometrical expressions depend upon an angle or part of a circle) which admits of indefinite increase.

(165.) The expressions for X and Y are not altered in value if we increase or diminish mx by 2π, 4π, 6π, &c.: that is, if we increase or diminish x by $\frac{2\pi}{m}$, $\frac{4\pi}{m}$, $\frac{6\pi}{m}$, &c., while t is unaltered: but the same cannot be asserted of any other value of x. Hence $\frac{2\pi}{m}$ is the value of each of the successive distances at which we find the water in the same state of disturbance, or $\frac{2\pi}{m}$ is the distance between one wave and the next. We shall call this the *length of a wave*, or the *amplitude of a wave*, and shall denote it by the symbol λ.

Length of wave.

(166.) The expressions for X and Y are not altered in value if we increase or diminish nt by 2π, 4π, 6π, &c., that is, if we increase or diminish t by $\frac{2\pi}{n}$, $\frac{4\pi}{n}$, $\frac{6\pi}{n}$, &c., while x is unaltered: but the same cannot be asserted of any other value of t. Hence $\frac{2\pi}{n}$ represents each of the intervals of time at which the water at any given place is successively in the same state of disturbance: we shall call this the *period* of a wave and shall denote it by the symbol τ.

Period of wave.

(167.) We shall now proceed to develope some of the practical interpretations of the equations just found.

(168.) Since X and Y both depend on $nt-mx$, if we put $t+t'$ for t, and $x+x'$ for x, we shall find new values X′ and Y′ depending on $nt-mx+nt'-mx'$; and these will be the same as X and Y if $nt'-mx'$ be zero: that is, at the end of the interval t', we shall find the water in a similar state of displacement, provided we examine it at the distance x' in advance: that is, in the time t' the wave will have travelled through the space x', or the velocity of the wave will be expressed by $\frac{x'}{t'}$; which, by virtue of the equation $nt'-mx'=0$, is the same as $\frac{n}{m}$. Hence

$$\text{Velocity of the wave}=\frac{n}{m}.$$

But we have found $n^2 = gm . \frac{\varepsilon^{mk} - \varepsilon^{-mk}}{\varepsilon^{mk} + \varepsilon^{-mk}}$: hence the velocity$= \sqrt{\frac{n^2}{m^2}} = \sqrt{\left\{\frac{g}{m} . \frac{\varepsilon^{mk} - \varepsilon^{-mk}}{\varepsilon^{mk} + \varepsilon^{-mk}}\right\}}$. This expression is not constant, but depends on m and k. From this it appears—

Inferences with regard to the velocity of waves.

1st. In water of given depth, the velocity of waves of all kinds is not the same, but depends upon m, or upon $\frac{2\pi}{m}$, or upon λ the length of the wave. (In this respect the waves of water are analogous to those of light, but are not analogous to those of sound.)

2nd. It follows immediately that, in water of given depth, the velocity of waves depends upon the interval of time at which they follow each other.

3rd. If the distance between the crests of the waves $\left(\lambda \text{ or } \frac{2\pi}{m}\right)$ is given, the velocity varies with the depth of the water.

4th. If the interval of time between successive waves $\left(\tau \text{ or } \frac{2\pi}{n}\right)$ is given, the velocity varies with the depth of the water.

(169.) The circumstances of waves of different lengths will easily be reduced to numerical calculation, if for n we put $\frac{2\pi}{\tau}$, and for m we put $\frac{2\pi}{\lambda}$; the equation between n and m is thus brought to the following form:

$$\tau^2 = \frac{2\pi\lambda}{g} . \frac{\varepsilon^{\frac{4\pi k}{\lambda}} + 1}{\varepsilon^{\frac{4\pi k}{\lambda}} - 1};$$

where it is to be remarked that $\varepsilon^{\frac{4\pi k}{\lambda}}$ is the number whose common logarithm is $\frac{4\pi k}{\lambda} \times 0{\cdot}434294$. If the time is expressed in seconds, and the space in feet, g (or the velocity which gravity communicates to a free body in one second), expressed in the same manner, is 32·16. From these data the following table is computed:

Table of the periods of waves.

TABLE I.

Depth of water, in feet.	Length of the wave, in feet.								
	1	10	100	1000	10,000	100,000	1000,000	10,000,000	100,000,000
	Corresponding period of wave, in seconds.								
1	0·442	1·873	17·645	176·33	1763·3	17633	176330	1763300	17633000
10	0·442	1·398	5·923	55·800	557·62	5576·2	55762	557620	5576200
100	0·442	1·398	4·420	18·730	176·45	1763·3	17633	176330	1763300
1000	0·442	1·398	4·420	13·978	59·230	558·00	5576·2	55762	557620
10,000	0·442	1·398	4·420	13·978	44·201	187·30	1764·5	17633	176330
100,000	0·442	1·398	4·420	13·978	44·201	139·78	592·30	5580	55762
1000,000	0·442	1·398	4·420	13·978	44·201	139·78	442·01	1873	17645

(170.) From these numbers the velocities are easily computed by dividing the length of the wave by the period. The following table contains the results:—

Table of the velocities of waves.

TABLE II.

Depth of water, in feet.	Length of the wave, in feet.									
	1	10	100	1000	10,000	100,000	1000,000	10,000,000	100,000,000	Infinite.
	Corresponding velocity of wave per second, in feet.									
1	2·2624	5·3390	5·6672	5·6710	5·6710	5·6710	5·6710	5·6710	5·6710	5·6710
10	2·2624	7·1543	16·883	17·921	17·933	17·933	17·933	17·933	17·933	17·933
100	2·2624	7·1543	22·624	53·390	56·672	56·710	56·710	56·710	56·710	56·710
1000	2·2624	7·1543	22·624	71·543	168·83	179·21	179·33	179·33	179·33	179·33
10,000	2·2624	7·1543	22·624	71·543	226·24	533·90	566·72	567·10	567·10	567·10
100,000	2·2624	7·1543	22·624	71·543	226·24	715·43	1688·3	1792·1	1793·3	1793·3
1000,000	2·2624	7·1543	22·624	71·543	226·24	715·43	2262·4	5339·0	5667·2	5671·0

The velocity of short waves does not depend on the depth.

The velocity of long waves depends only on the depth.

(171.) From these numbers it appears that,

1st. When the length of the wave is not greater than the depth of the water, the velocity of the wave depends (sensibly) only on its length, and is proportional to the square root of its length.

2nd. When the length of the wave is not less than a thousand times the depth of the water, the velocity of the wave depends (sensibly) only on the depth, and is proportional to the square root of the depth. It is, in fact, the same as the velocity which a free body would acquire by falling from rest, under the action of gravity, through a height equal to half the depth of the water.

3rd. For intermediate proportions of the length of the wave and the depth of the water, the velocity of the wave can be found only by means of the general equation.

(172.) The values in the extreme cases will easily be found by expansion of the general formula. Thus, when λ is small, or $\frac{k}{\lambda}$ large, $\varepsilon^{\frac{4\pi k}{\lambda}}$ is very large: $\frac{\varepsilon^{\frac{4\pi k}{\lambda}}+1}{\varepsilon^{\frac{4\pi k}{\lambda}}-1}$ does not sensibly differ from unity, and $\tau^2=\frac{2\pi\lambda}{g}$: whence the velocity $=\frac{\lambda}{\tau}=\sqrt{\frac{g\lambda}{2\pi}}$. When λ is large, or $\frac{k}{\lambda}$ small, $\varepsilon^{\frac{4\pi k}{\lambda}}=1+\frac{4\pi k}{\lambda}$ nearly, and $\tau^2=\frac{\lambda^2}{gk}$; whence the velocity $=\frac{\lambda}{\tau}=\sqrt{gk}$.

(173.) There is one numerical value of τ which, in reference to future applications, deserves special consideration—it is that corresponding to the wave originally produced by the action of the Sun and Moon. This wave may with propriety be called the tide-wave. But for clearness we may remark (although anticipating another part of this Section), that there are two distinct classes of waves bearing the name *tide-wave*. One of them is produced by the immediate action of the forces of the Sun and Moon, and its highest or its lowest point is always at a determinate distance from that place in the canal at which the disturbing forces vanish; the velocity, therefore, of this wave does not depend at all upon the depth of the water. This we shall call the *forced tide-wave*. Coexistent with this there may be, and generally is, a wave in which the period τ is the same, but in which λ is different, and the velocity consequently different; produced originally by the action of the Sun and Moon, but not affected by their action in regard to its velocity of propagation: this kind of tide-wave is the only one which is sensible in narrow seas and rivers. This we shall call the *free tide-wave*. Our present computations belong to the *free* tide-wave only.

(174.) The interval of time (τ) for the semidiurnal tide-wave is not constant; but it may be considered as 12 hours 24 minutes, or 44,640 seconds. Now we have found, Table II., that with a depth of water of 100,000 feet, or 20 miles nearly, a wave of any length exceeding 100,000,000 feet will travel with a velocity sensibly independent of its length; and that even if its length be only 10,000,000 feet, the velocity will not differ from that of a longer wave by $\frac{1}{1500}$ part. The former wave, by Table I., would have the period 55,762 seconds; the latter would have the period 5580 seconds. It is clear that the period of the tide-wave is sufficient to justify us in assuming the velocity of the *free* tide-wave as equal to that which belongs properly to a wave of indefinite length in water of the same depth. On this principle the following table is computed:—

Table for the semidiurnal free tide-wave.

TABLE III.

Depth of water, in feet.	Velocity of free tide-wave per second, in feet.	Length of free tide-wave, in miles.	Space described by free tide-wave in one hour, in miles.	Depth of water, in feet.	Velocity of free tide-wave per second, in feet.	Length of free tide-wave, in miles.	Space described by free tide-wave in one hour, in miles.
1	5·671	47·946	3·8666	5000	401·00	3390·2	273·41
4	11·342	95·891	7·7332	6000	439·27	3713·8	299·50
10	17·933	151·62	12·227	7000	474·47	4011·4	323·50
20	25·361	214·42	17·292	8000	507·23	4288·3	345·84
40	35·867	303·24	24·455	9000	538·00	4548·5	366·82
60	43·927	371·38	29·950	10000	567·10	4794·6	386·66
80	50·723	428·83	34·584	15000	694·54	5872·1	473·55
100	56·710	479·46	38·666	20000	802·00	6780·5	546·82
200	80·200	678·05	54·682	25000	896·66	7580·9	611·36
400	113·42	958·91	77·332	30000	982·25	8304·4	669·71
600	138·91	1174·4	94·711	35000	1060·9	8969·7	723·37
800	160·40	1356·1	109·36	40000	1134·2	9589·1	773·32
1000	179·33	1516·2	122·27	45000	1203·0	10171	820·22
2000	253·61	2144·2	172·92	50000	1268·1	10721	864·59
3000	310·62	2626·1	211·78	55000	1330·0	11244	906·80
4000	358·67	3032·4	244·55	60000	1389·1	11744	947·11

(175.) The diurnal tide-wave, and others connected with the tides, of which we shall have occasion to speak, so far as they are *free* tide-waves, may all be considered as moving with the same velocity. The table will, therefore, apply to them, excepting only the column of the *length of the tide-wave*, the numbers in which must be doubled for the diurnal tide-wave.

(176.) We shall now proceed to examine the circumstances of the motion of each particle of water in wave-motion. And, first, we shall consider the values of the extreme extent of motion of each particle.

Formulæ for extreme motion of individual particles.

(177.) We have found (161.) that the horizontal displacement X of any particle, whose height above the bottom is y, is represented by $A(\varepsilon^{my}+\varepsilon^{-my})\cos(nt-mx-B)$. The extreme values of this quantity are $-A(\varepsilon^{my}+\varepsilon^{-my})$ when $nt-mx-B$ is an odd multiple of 180°, and $+A(\varepsilon^{my}+\varepsilon^{-my})$ when $nt-mx-B$ is an even multiple of 180°. And (161.) the vertical displacement Y of the same particle is represented by $-A(\varepsilon^{my}-\varepsilon^{-my})\sin(nt-mx-B)$; the extreme values of which are $-A(\varepsilon^{my}-\varepsilon^{-my})$ when $nt-mx-B=90°+$ an even multiple of 180°, and $+A(\varepsilon^{my}-\varepsilon^{-my})$ when $nt-mx-B=90°+$ an odd multiple of 180°. Hence $A(\varepsilon^{my}+\varepsilon^{-my})$ and $A(\varepsilon^{my}-\varepsilon^{-my})$ may be considered as representing the greatest extent of horizontal and vertical motions; or, omitting A (as our object is only to show the proportion of the various motions), and putting $\frac{2\pi}{\lambda}$ for m, the horizontal and vertical motions will be represented respectively by $\varepsilon^{\frac{2\pi y}{\lambda}}+\varepsilon^{-\frac{2\pi y}{\lambda}}$ and $\varepsilon^{\frac{2\pi y}{\lambda}}-\varepsilon^{-\frac{2\pi y}{\lambda}}$. At the bottom, where $y=0$, the extreme horizontal motion will be represented by $\varepsilon^{0}+\varepsilon^{0}=2$. By means of these formulæ the following table is computed :—

Table of proportional extent of horizontal and vertical motions.

TABLE IV.

Greatest extent of the horizontal and vertical displacements of the particles at different depths, for different proportions of the length of the wave to the whole depth: the greatest horizontal displacement of the particles at the bottom being represented by 2.

Depth below the surface.	Values of $\frac{k}{\lambda}$.					
	10000		1000		100	
	Corresponding displacements of the particle.					
	Horizontal.	Vertical.	Horizontal.	Vertical.	Horizontal.	Vertical.
At surface	1(27287 fig.)	1(27287 fig.)	5(2728 fig.)	5(2728 fig.)	7(272 fig.)	7(272 fig.)
$\frac{1}{10}$ whole depth	2(24558 fig.)	2(24558 fig.)	6(2455 fig.)	6(2455 fig.)	3(245 fig.)	3(245 fig.)
$\frac{2}{10}$,, ,,	4(21829 fig.)	4(21829 fig.)	9(2182 fig.)	9(2182 fig.)	1(218 fig.)	1(218 fig.)
$\frac{3}{10}$,, ,,	8(19100 fig.)	8(19100 fig.)	1(1910 fig.)	1(1910 fig.)	1(191 fig.)	1(191 fig.)
$\frac{4}{10}$,, ,,	1(16372 fig.)	1(16372 fig.)	1(1637 fig.)	1(1637 fig.)	5(163 fig.)	5(163 fig.)
$\frac{5}{10}$,, ,,	3(13643 fig.)	3(13643 fig.)	2(1364 fig.)	2(1364 fig.)	2(136 fig.)	2(136 fig.)
$\frac{6}{10}$,, ,,	6(10914 fig.)	6(10914 fig.)	3(1091 fig.)	3(1091 fig.)	1(109 fig.)	1(109 fig.)
$\frac{7}{10}$,, ,,	1(8186 fig.)	1(8186 fig.)	4(818 fig.)	4(818 fig.)	7(81 fig.)	7(81 fig.)
$\frac{8}{10}$,, ,,	2(5457 fig.)	2(5457 fig.)	5(545 fig.)	5(545 fig.)	3(54 fig.)	3(54 fig.)
$\frac{9}{10}$,, ,,	5(2728 fig.)	5(2728 fig.)	7(272 fig.)	7(272 fig.)	1(27 fig.)	1(27 fig.)
At bottom	2	0	2	0	2	0

Depth below the surface.	Values of $\frac{k}{\lambda}$.					
	10		1		$\frac{1}{10}$	
	Corresponding displacements of the particle.					
	Horizontal.	Vertical.	Horizontal.	Vertical.	Horizontal.	Vertical.
At surface	1(27 fig.)	1(27 fig.)	535·429	535·425	2·40792	1·34094
$\frac{1}{10}$ whole depth	3(24 fig.)	3(24 fig.)	285·651	285·643	2·32838	1·19220
$\frac{2}{10}$,, ,,	6(21 fig.)	6(21 fig.)	152·398	152·384	2·25802	1·04816
$\frac{3}{10}$,, ,,	1(19 fig.)	1(19 fig.)	81·3122	81·2876	2·19658	0·90826
$\frac{4}{10}$,, ,,	2(16 fig.)	2(16 fig.)	43·3961	43·3499	2·14381	0·77195
$\frac{5}{10}$,, ,,	4(13 fig.)	4(13 fig.)	23·1825	23·0961	2·09951	0·63869
$\frac{6}{10}$,, ,,	8(10 fig.)	8(10 fig.)	12.4257	12·2637	2·06349	0·50795
$\frac{7}{10}$,, ,,	1(8 fig.)	1(8 fig.)	6·73766	6·43398	2·03564	0·37922
$\frac{8}{10}$,, ,,	286690	286690	3·79812	3·22888	2·01581	0·25199
$\frac{9}{10}$,, ,,	535·4	535·4	2·40793	1·34093	2.00395	0·12575
At bottom	2·0	0·0	2·00000	0·00000	2·00000	0·00000

TABLE IV.—*continued.*

Depth below the surface.	Values of $\frac{k}{\lambda}$.					
	$\frac{1}{100}$		$\frac{1}{1000}$		$\frac{1}{10000}$	
	Corresponding displacements of the particle.					
	Horizontal.	Vertical.	Horizontal.	Vertical.	Horizontal.	Vertical.
At surface	2·003950	0·125744	2·000040	0·012566	2·000001	0·001257
$\frac{1}{10}$ whole depth	2·003199	0·113155	2·000032	0·011310	2·000001	0·001131
$\frac{2}{10}$ " "	2·002527	0·100571	2·000025	0·010053	2·000001	0·001005
$\frac{3}{10}$ " "	2·001935	0·087991	2·000019	0·008797	2·000000	0·000880
$\frac{4}{10}$ " "	2·001421	0·075415	2·000014	0·007540	2·000000	0·000754
$\frac{5}{10}$ " "	2·000987	0·062841	2·000010	0·006284	2·000000	0·000628
$\frac{6}{10}$ " "	2·000632	0·050270	2·000006	0·005026	2·000000	0·000502
$\frac{7}{10}$ " "	2·000355	0·037701	2·000004	0·003770	2.000000	0·000378
$\frac{8}{10}$ " "	2·000158	0·025132	2·000002	0·002514	2·000000	0·000252
$\frac{9}{10}$ " "	2·000040	0·012566	2·000001	0·001257	2·000000	0·000126
At bottom	2·000000	0·000000	2·000000	0·000000	2·000000	0·000000

In this table, by 1(27287 figures) is meant the figure 1 followed by 27287 significant figures before the decimal point; and similarly 2(24558 figures) is intended to express the figure 2 followed by 24558 figures before the decimal point; and so for the others.

(178.) From inspection of this table the following points are evident:

When the wave is short, the motion is not sensible except near the surface.

1st. When the depth is great in comparison with the length of the wave (as in the case of ordinary waves in the open sea), the motion of the water at any great depth below the surface is wholly insignificant in comparison with that at the surface. The following rule may be convenient. As the depth below the surface proceeds in arithmetical progression, the motion diminishes in geometrical progression; and at a depth equal to the length of the wave the motion is diminished to $\frac{1}{535 \cdot 4}$ of that at the surface. This rule will be demonstrated by remarking that when $\frac{k}{\lambda}$ is large and therefore $\frac{y}{\lambda}$ is large (the depths below the surface not being extremely great) $\varepsilon^{mk}+\varepsilon^{-mk}$, or $\varepsilon^{\frac{2\pi}{\lambda}}+\varepsilon^{-\frac{2\pi k}{\lambda}}$, and $\varepsilon^{my}+\varepsilon^{-my}$, or $\varepsilon^{\frac{2\pi y}{\lambda}}+\varepsilon^{-\frac{2\pi y}{\lambda}}$, will, as to sense, be reduced to their first terms $\varepsilon^{\frac{2\pi k}{\lambda}}$ and $\varepsilon^{\frac{2\pi y}{\lambda}}$: and therefore the motion at the depth $k-y$ will $=$ motion at surface $\times \frac{\varepsilon^{\frac{2\pi y}{\lambda}}}{\varepsilon^{\frac{2\pi k}{\lambda}}} =$ motion at surface $\times \varepsilon^{-\frac{2\pi}{\lambda}(k-y)}$, or the motion diminishes in geometrical progression, as the depth $k-y$ increases in arithmetical progression. And if $k-y=\lambda$, the motion at the depth $\lambda=$motion at surface $\times \varepsilon^{-2\pi}=$ motion at surface $\times \frac{1}{535 \cdot 4}$.

The horizontal and vertical motions are equal.

(179.) 2d. On the same supposition, the greatest horizontal motion of any particle is equal to its greatest vertical motion: except for those particles very near to the bottom, where the whole motion is insensible.

When the wave is long, the horizontal motion is nearly the same at all depths.

(180.) 3d. When the length of the wave is great in comparison with the depth of the water, (as in the case of tide-waves,) the horizontal motion is sensibly the same from the surface to the bottom, and the vertical motion for different particles varies in the same proportion as their height above the bottom.

The vertical motion is much less than the horizontal motion.

(181.) 4th. On the same supposition the vertical motion of the superficial particles is very much less than their horizontal motion. The proportion of the vertical motion to the horizontal motion is $\frac{\varepsilon^{\frac{2\pi k}{\lambda}}-\varepsilon^{-\frac{2\pi k}{\lambda}}}{\varepsilon^{\frac{2\pi k}{\lambda}}+\varepsilon^{-\frac{2\pi k}{\lambda}}}$: and when $\frac{2\pi k}{\lambda}$ is small, $\varepsilon^{\frac{2\pi k}{\lambda}}-\varepsilon^{-\frac{2\pi k}{\lambda}}$ is nearly equal to $\frac{4\pi k}{\lambda}$, and $\varepsilon^{\frac{2\pi k}{\lambda}}+\varepsilon^{-\frac{2\pi k}{\lambda}}$ is nearly equal to 2: and thus the proportion of the vertical motion of the superficial particles to the horizontal motion is $\frac{4\pi k}{2\lambda}$ $=6 \cdot 2832 \times \frac{k}{\lambda}$.

When the waves are short, each particle at the surface moves uniformly in a circle.

(182.) We shall now examine the curve described by any individual particle. And first, the motion of a particle at the surface in ordinary small waves. We have seen that, in this case, the horizontal displacement $X = A . \varepsilon^{\frac{2\pi k}{\lambda}} . \cos(nt - mx - B)$ $\left\{\text{neglecting the insignificant term } \varepsilon^{-\frac{2\pi k}{\lambda}}\right\}$, which we will call $C . \cos(nt - mx - B)$. In like manner, the vertical displacement $Y = -A . \varepsilon^{\frac{2\pi k}{\lambda}} . \sin(nt - mx - B) = -C . \sin(nt - mx - B.)$ Therefore $\sqrt{X^2 + Y^2}$, or the particle's whole distance from the point whose co-ordinates are x and y (which do not vary with the time) is $= C$. That is, any particle is, at any instant whatever, somewhere in the circumference of a circle, whose centre is the fixed point defined by the co-ordinates x and y, and whose radius is C or $A . \varepsilon^{\frac{2\pi k}{\lambda}}$. Let θ be the angle made with the vertical by the radius joining the particle and the point whose ordinates are x, y; considered positive when the particle is *above* that point, and *advanced before* it. Then $\tan\theta = \frac{X}{Y} = -\frac{C . \cos(nt - mx - B)}{C . \sin(nt - mx - B)} = -\cot(nt - mx - B) = \tan(nt - mx - B + 90°)$, or $\theta = nt - mx - B + 90°$. As the time t increases uniformly, the angle θ increases uniformly. Consequently the particle revolves uniformly in the circle of which we have spoken; moving forwards when at the highest part of the circle, and backwards when at the lowest part. The same applies to particles below the surface, except those nearly in contact with the bottom.

In all other cases, each particle moves in an ellipse.

(183.) In all other cases, and especially when the length of the wave is great in proportion to the depth of the water, or $\frac{k}{\lambda}$ is small, the coefficients entering into the expressions (which are the same as the greatest motions, whose proportions are given by the numbers in Table IV.) are very different. Representing X by $C . \cos\overline{nt - mx - B}$ and Y by $-c . \sin\overline{nt - mx - B}$, we shall have $\frac{X^2}{C^2} + \frac{Y^2}{c^2} = 1$: the equation to an ellipse whose semiaxes are C and c. The particle therefore will always be found in the circumference of an ellipse whose centre is the point of which the co-ordinates are x, y. In the case of the tide-wave, this ellipse is extremely flat.

The water at the top of the wave moves most rapidly forward.

(184.) But in the tide-wave, and every other wave, which travels along a channel in the manner which we have supposed in this subsection, this law is universal: that the water is travelling forward with its greatest speed at the time of high water, or at the top of the wave. This follows clearly enough from the theorems that we have laid down (that in small waves every particle moves uniformly in a circle, and therefore each particle has its most rapid motion forwards when it is highest: and that in long waves the motions in the two ordinates are expressed by the same law with different coefficients): but it is so important that this should be clearly understood, that we think it necessary expressly to call the reader's attention to it. It will be easily shown by remarking that the horizontal velocity or $\frac{dX}{dt} = -n C . \sin\overline{nt - mx - B}$, and therefore the horizontal velocity forwards is in a constant proportion to Y the elevation of the water above its mean place. Thus when the water is highest, the velocity forward is greatest: when the water is at its mean height (whether before high water or after high water), Y is 0 and the water's velocity is 0, or it is still water: when the water is at its greatest depression, or Y has its greatest negative value, the water is running backwards with its greatest velocity. We shall consider this as the standard case in the theory of waves; and shall occasionally refer to it in noting the deviations from these laws which occur in particular circumstances.

That in the hollow of the wave moves most rapidly backwards.

(185.) Reverting now to the general equations of (150.) for shallow waves, supposing $F = 0$, namely, $Y = -\int_y \frac{dX}{dx}$ (0 to y): $\frac{d^2X}{dt^2} = \frac{d}{dx}\left\{-gK - \int_y \frac{d^2Y}{dt^2} (y \text{ to } k)\right\}$ we may make the following remarks.

First: having found that this equation is satisfied by a function of $+nt$, as $A(\varepsilon^{my} + \varepsilon^{-my}) . \cos(nt - mx)$, we can at once assert that it will be satisfied by the same function of $-nt$, or $A(\varepsilon^{my} + \varepsilon^{-my}) \cos(-nt - mx)$, or

$$A(\varepsilon^{my} + \varepsilon^{-my}) \cos(nt + mx).$$

Opposite waves.

For the only way in which the multiplier n affects the substitution of these quantities in the equation is by its influence in the second differential coefficients $\frac{d^2X}{dt^2}$ and $\frac{d^2Y}{dt^2}$: and these, by differentiation, obtain the same factor whether $+n$ or $-n$ be the multiplier of t. Thus, if $X = A(\varepsilon^{my} + \varepsilon^{-my}) \cos(nt - mx)$, $\frac{d^2X}{dt^2} = -n^2 X$: if $X = A(\varepsilon^{my} + \varepsilon^{-my}) \cos(-nt - mx)$, $\frac{d^2X}{dt^2}$ still $= -n^2 X$. Now an expression depending on $\cos(-nt - mx)$ or $\cos(nt + mx)$ will imply a wave, in the same manner as one depending on $\cos(nt - mx)$, but with this difference: that whereas in the latter case the wave moves in the direction of x, on the contrary, in the former case, the wave moves in the opposite direction, but with the same speed. This will be seen from the same reasoning as in (168.).

Combination of several waves.

(186.) Secondly: Having found any number of functions X′, X″, X‴, &c., with their corresponding functions Y′, Y″, Y‴, &c., K′, K″, K‴, &c., each of which satisfies the equations

$$\mathrm{Y}'=-\int_y \frac{d\mathrm{X}'}{dx},\quad \frac{d^2\mathrm{X}'}{dt^2}=\frac{d}{dx}\left\{-g\mathrm{K}'-\int_y \frac{d^2\mathrm{Y}'}{dt^2}\,(y \text{ to } k)\right\}, \text{\&c.}$$

Subsect. Motion of Waves in Canal of uniform Depth.

we see at once that the sum X′+X″+X‴+ &c., will satisfy the same equation. For upon adding together all the separate equations formed from X′, X″, X‴, &c. we produce the very same equation which would be formed by substituting the whole quantity X′+X″+X‴+, &c. Now each of the functions X′, X″, &c., with its related functions Y′, K′, Y″, K″, &c, represents a wave or system of waves; and our theorem therefore amounts to this: "If there are any number of systems of shallow waves which can exist separately on water, these waves can all exist together upon the water: the elevations being added at the places where they coincide, or the depression of one being subtracted from the elevation of another where the place of depression of one wave corresponds to the place of elevation of another, &c."

Combination of equal opposite waves.

(187.) One instance of this coexistence of waves may be mentioned as a matter of interest. Suppose two waves, equal in period, and equal in magnitude, to move in opposite directions upon a canal. In one of these, the expression for X′ will be

$$\mathrm{A}.(\varepsilon^{my}+\varepsilon^{-my})\cos(nt-mx+\mathrm{B});$$

in the other, the expression for X″ will be

$$\mathrm{A}.(\varepsilon^{my}+\varepsilon^{-my})\cos(nt+mx+\mathrm{B}').$$

The sum of these gives for the compounded wave X=X′+X″=

$$2\mathrm{A}.(\varepsilon^{my}+\varepsilon^{-my}).\cos\left(nt+\frac{\mathrm{B}+\mathrm{B}'}{2}\right).\cos\left(mx+\frac{\mathrm{B}'-\mathrm{B}}{2}\right).$$

And the corresponding value of $\mathrm{Y}=-\int_y \frac{d\mathrm{X}}{dx}=$

$$2\mathrm{A}.(\varepsilon^{my}-\varepsilon^{-my}).\cos\left(nt+\frac{\mathrm{B}+\mathrm{B}'}{2}\right).\sin\left(mx+\frac{\mathrm{B}'-\mathrm{B}}{2}\right),$$

from which K or the elevation of the surface =

$$2\mathrm{A}.(\varepsilon^{mk}-\varepsilon^{-mk}).\cos\left(nt+\frac{\mathrm{B}+\mathrm{B}'}{2}\right).\sin\left(mx+\frac{\mathrm{B}'-\mathrm{B}}{}\right).$$

From inspection of these expressions we may see that

Produces a stationary wave.

(188.) First, as neither X nor Y depends upon such a quantity as $pt-qx$, there is no appearance whatever of a progressive wave.

Each particle moves in a straight line.

(189.) Secondly; the displacement of any particle in the direction of x depends upon $\cos\left(nt+\frac{\mathrm{B}+\mathrm{B}'}{2}\right)$, (the factor $\cos\left(mx+\frac{\mathrm{B}'-\mathrm{B}}{2}\right)$ being constant for that particle,) and the displacement of the same particle in the direction of y depends also upon $\cos\left(nt+\frac{\mathrm{B}+\mathrm{B}'}{2}\right)$. Therefore, for any particle, the horizontal and vertical displacements are always in the same proportion, or each particle moves in a straight line.

(190.) Thirdly; at the places where $\cos\left(mx+\frac{\mathrm{B}'-\mathrm{B}}{2}\right)=0$, or where $mx+\frac{\mathrm{B}'-\mathrm{B}}{2}=\frac{\pi}{2}$, or $\frac{3\pi}{2}$, or $\frac{5\pi}{2}$, &c., there is no horizontal motion whatever, but there is great vertical motion.

(191.) Fourthly; at the places where $\sin\left(mx+\frac{\mathrm{B}'-\mathrm{B}}{2}\right)=0$, or where $mx+\frac{\mathrm{B}'-\mathrm{B}}{2}=0$, or π, or 2π, &c., there is no vertical motion whatever, but there is great horizontal motion.

Subsection 3.—Theory of Long Waves, in which the Elevation of the Water bears a sensible proportion to the depth of the Canal.

(192.) Hitherto we have considered the displacements of the particles to be so small that the squares and higher powers of those displacements might be neglected. In the following problem we shall take into account the higher orders of the displacements.

Problem.—To investigate the motion of a very long wave, as the tide-wave, in a canal whose depth is so small that the range of elevation and depression of the surface bears a considerable proportion to the whole depth.

Limitations permitted when the wave is very long.

(193.) We have seen, (180.) and (181.), that, for the tide-wave, the horizontal motion of the particles at different depths in the same vertical line is sensibly the same, and that the vertical motion is extremely small in comparison with the horizontal motion. We shall, therefore, assume that the horizontal motion is uniform for all particles in the same vertical; or that particles which are once in a vertical line remain in a vertical line. And we shall assume that, in estimating the pressure at any point, the height of water above that point is all that needs to be considered: the part represented in the former equations by $\frac{d^2Y}{dt^2}$ being insignificant on account of the smallness of the vertical motion. These assumptions are similar to those in (68.).

(194.) Let x be the horizontal ordinate corresponding to one vertical line of particles in their state of rest: $x+h$ that corresponding to another vertical line of particles; k the depth of the water in a state of rest. In the state of wave-motion, let the first-mentioned vertical line be displaced at the time t through the horizontal space X, so that its horizontal ordinate is $x+X$ (x being independent of t); and let V or $k+K$ be the corresponding depth of the water. Then, the horizontal ordinate which was x has now become $x+X$; that which was $x+h$ has now become $x+h+X+\frac{dX}{dx}h$ nearly: therefore the intermediate horizontal space which was h has now become $h\left(1+\frac{dX}{dx}\right)$. And the vertical elevation which was k has now become $k+K$ or V. Consequently, the volume which was expressed by $h\times k$ is now expressed by $h\left(1+\frac{dX}{dx}\right)\times V$. These expressions must be equal: therefore we have $h\times k=h\left(1+\frac{dX}{dx}\right)\times V$, or

$$V=\frac{k}{1+\frac{dX}{dx}}.$$

This is the equation of continuity for this case.

Equation of continuity, supposing the displacement to be large.

(195.) Now if we consider the pressure upon any particle whose coordinates are $x+X$ and y, as produced by the elevation of the water above it, we shall find it to be represented by the weight of a column of water whose length is $V-y$. In like manner, the pressure upon the particle whose ordinates are $x+h'+X+\frac{dX}{dx}h'$ and y, is represented by the weight of a column of water whose length is $V+\frac{dV}{dx}h'-y$. And as the pressures are equal in all directions, the horizontal pressures on the included horizontal column whose length is $h'\left(1+\frac{dX}{dx}\right)$, are the weights of columns of water, one represented by $V-y$, tending to push it forwards, and one represented by $V+\frac{dV}{dx}h'-y$, tending to push it backwards. Or, the pressure tending to push forwards the column $h'\left(1+\frac{dX}{dx}\right)$ is the weight of a column $\frac{-dV}{dx}h'$; and, therefore, the acceleration produced in the direction of x is $-g\frac{dV}{dx}\cdot\frac{1}{1+\frac{dX}{dx}}$; or $\frac{d^2(x+X)}{dt^2}=-g\frac{dV}{dx}\cdot\frac{1}{1+\frac{dX}{dx}}$. Observing that x is independent of t, and putting for V its value found above, we obtain the equation

$$\frac{d^2X}{dt^2}=gk\,\frac{\frac{d^2X}{dx^2}}{\left(1+\frac{dX}{dx}\right)^2},$$

in which equation $\left(\text{as the variations of V are not to be neglected, and as those variations depend on }\frac{dX}{dx}\right)$ we must not neglect $\frac{dX}{dx}$, although we may consider it small.

Equation of equal pressure.

(196.) This equation may be solved to any degree of approximation by successive substitution. Expanding the fraction, and (for convenience) putting v^2 for gk, the equation may be thus expressed:

$$\frac{d^2X}{dt^2}-v^2.\frac{d^2X}{dx^2}=v^2.\frac{d^2X}{dx^2}\times\left\{-3\frac{dX}{dx}+6\left(\frac{dX}{dx}\right)^2-\&c.\right\}.$$

First we may obtain an approximate value for X by neglecting all the terms on the second side of the equation; then, substituting that value in the first term on the second side, we shall have a more approximate value; and so on.

Solution to first approximation.

(197.) First approximation; $\frac{d^2X}{dt^2}-v^2\frac{d^2X}{dx^2}=0$. To solve this equation let $vt-x=u$, $vt+x=w$; and consider X as a function of u and w. Then $\frac{dX}{dt}=\frac{dX}{du}.\frac{du}{dt}+\frac{dX}{dw}.\frac{dw}{dt}=v\left(\frac{dX}{du}+\frac{dX}{dw}\right)$. Call this X′. Then $\frac{d^2X}{dt^2}=\frac{dX'}{dt}=v\left(\frac{dX'}{du}+\frac{dX'}{dw}\right)=v^2\left(\frac{d^2X}{du^2}+2\frac{d^2X}{du\,dw}+\frac{d^2X}{dw^2}\right)$. Also $\frac{dX}{dx}=\frac{dX}{du}.\frac{du}{dx}+\frac{dX}{dw}.\frac{dw}{dx}=-\frac{dX}{du}+\frac{dX}{dw}$. Call this X″. Then $\frac{d^2X}{dx^2}=\frac{dX''}{dx}=-\frac{dX''}{du}+\frac{dX''}{dw}=\frac{d^2X}{du^2}-2\frac{d^2X}{du\,dw}+\frac{d^2X}{dw^2}$. Substituting these in the equation, we have $4v^2.\frac{d^2X}{du\,dw}=0$, or $\frac{d^2X}{du\,dw}=0$. Integrating successively with regard to u and w, and remarking that the arbitrary constant at each integration may be an arbitrary function of the other variable, $\frac{dX}{dw}=\psi'(w)$ $X=\phi(u)+\psi(w)$. Restoring the expressions for u and w, $X=\phi(vt-x)+\psi(vt+x)$, where ϕ and ψ may be any functions whatever. The second term represents a wave rolling backwards, but as we do not at present consider such a wave, we shall make that term $=0$. The first expresses that we may assume any law whatever, provided that $vt-x$ is the subject of it; but in the Theory of Tides we must assume that, in the mouth of the channel connected with the open sea, the disturbance depends upon $\cos(nt+A)$, n and A being independent of the time: and, therefore, we must assume the form of X here to be

$$a\cos(mvt-mx),$$

where $mv=n$. For convenience, we omit to add a constant to the arc $mvt-mx$, as the same effect may be produced by altering the epoch from which t is measured. The assumption of this form for X will not prevent us from adding to it a small term of the form $a^2.\cos(2mvt-2mx)$, or $a^2.\sin(2mvt-2mx)$, if we should find it necessary, as those terms also satisfy the equation $\frac{d^2X}{dt^2}-v^2\frac{d^2X}{dx^2}=0$.

Solution to second approximation.

(198.) Second approximation. With the value $X=a.\cos(mvt-mx)$, we have $\frac{dX}{dx}=ma.\sin(mvt-mx)$, $\frac{d^2X}{dx^2}=-m^2a.\cos(mvt-mx)$; and substituting these values in the first term on the second side of the equation,

$$\frac{d^2X}{dt^2}-v^2\frac{d^2X}{dx^2}=\frac{3}{2}a^2v^2m^3.\sin(2mvt-2mx),$$

or

$$4v^2\frac{d^2X}{du\,dw}=\frac{3}{2}a^2v^2m^3.\sin 2mu,$$

or

$$\frac{d^2X}{du\,dw}=\frac{3}{8}a^2m^3.\sin 2mu.$$

Integrating with respect to u,

$$\frac{dX}{dw}=\psi'(w)-\frac{3}{16}a^2m^2.\cos 2mu.$$

Integrating again with respect to w,

$$X=\phi(u)+\psi(w)-\frac{3}{16}a^2m^2.w.\cos 2mu;$$

or

$$X=\phi(vt-x)+\psi(vt+x)-\frac{3}{16}a^2m^2.(vt+x).\cos(2mvt-2mx).$$

The arbitrary functions must be so chosen that the result of this solution may be consistent, to the first order of the small quantity a, with the first approximate solution; and may also enable us to satisfy the tidal condition at the mouth of the river. For this purpose the term $vt.\cos(2mvt-2mx)$ must be destroyed; because its existence would imply that the rise and fall of the water at the river's mouth are constantly increasing from tide to tide. We shall, therefore, take for $\phi(vt-x)+\psi(vt+x)$ the following quantity, in which every term is a function of $vt-x$:

$$a\cos(mvt-mx)+\frac{3}{16}a^2m^2(vt-x).\cos(2mvt-2mx)+ca^2.\cos(2mvt-2mx)$$
$$+c'a^2.\sin(2mvt-2mx),$$

which gives for X

$$a.\cos(mvt-mx)-\frac{3}{8}a^2m^2.x.\cos(2mvt-2mx)$$
$$+\ ca^2.\cos(2mvt-2mx)$$
$$+\ c'a^2.\sin(2mvt-2mx)\,;$$

where c and c' may be hereafter chosen so as to satisfy the condition of communicating with the tide of the open sea.

(199.) Taking the expression found for X, we obtain

$$\frac{dX}{dx}=am.\sin(mvt-mx)-\frac{3}{4}a^2m^2.x.\sin(2mvt-2mx)$$
$$+\ 2a^2m\,c.\sin(2mvt-2mx)$$
$$-a^2\left(\frac{3}{8}m^2+2mc'\right)\cos(2mvt-2mx)\,;$$

and, substituting this in the expression $V=\dfrac{k}{1+\dfrac{dX}{dx}}$, we find

$$V=k\left\{\begin{array}{l}1-am\sin(mvt-mx)+a^2\dfrac{m^2}{2}\\ \qquad+\dfrac{3}{4}a^2m^2.x.\sin(2mvt-2mx)\\ \qquad-\ 2a^2mc.\sin(2mvt-2mx)\\ \qquad+a^2\left(-\dfrac{m^2}{2}+\dfrac{3m^2}{8}+2mc'\right)\cos(2mvt-2mx)\end{array}\right\};$$

This, however, is the expression for the height of the water at the present place of those particles whose horizontal ordinate was originally $=x$. If we wish to find the height of the water at the place whose ordinate, measured on the bank of the canal, is x', we must consider that the original ordinate of the particles now there was x, where $x+X=x'$, or $x=x'-X=x'-X'$ nearly $=x'-a.\cos(mvt-mx')$ nearly; and this quantity must be substituted for x in the expression for V. In the term multiplied by a, instead of $\sin(mvt-mx)$, we shall have

$$\sin\{mvt-mx'+ma.\cos(mvt-mx')\}=\sin(mvt-mx')+\frac{ma}{2}+\frac{ma}{2}\cos(2mvt-2mx')\text{ nearly.}$$

The terms multiplied by a^2 require no alteration, as the alteration would introduce terms depending on a^3, to which order we have not proceeded in our approximation. Thus we find for the elevation of the water at the point whose ordinate is x',

$$V=k\left\{\begin{array}{l}1-am\sin(mvt-mx')+\dfrac{3}{4}a^2m^2x'.\sin(2mvt-2mx')\\ \qquad-\ 2a^2mc.\sin(2mvt-2mx')\\ \qquad+a^2\left(-\dfrac{m^2}{2}-\dfrac{m^2}{2}+\dfrac{3m^2}{8}+2mc'\right)\cos(2mvt-2mx')\end{array}\right\}.$$

(200.) Now suppose x' to be measured from the point where the canal communicates with the open sea. The expression for the elevation of the water at that point will depend upon $\sin nt$ or $\sin mvt$, (by the laws of the tides which we shall hereafter investigate,) but not upon $\sin 2mvt$ or $\cos 2mvt$: and, therefore, when $x'=0$, the terms depending on $\sin(2mvt-2mx')$ and $\cos(2mvt-2mx')$ must vanish. We must, therefore, assume

$$c=0,\quad -\frac{m^2}{2}-\frac{m^2}{2}+\frac{3m^2}{8}+2mc'=0.$$

Thus we find at length,

$$V=k\left\{1-am.\sin(mvt-mx')+\frac{3}{4}a^2m^2.\,x'.\,\sin(2mvt-2mx')\right\};$$

or, putting b for am,

Expression for tidal elevation in the river.

$$V=k\left\{1-b\,.\,\sin(mvt-mx')+\frac{3}{4}b^2.\,mx'.\,\sin(2mvt-2mx')\right\}:$$

and the elevation of the water above its mean height is expressed by

$$K = -bk.\sin(mvt - mx') + \frac{3}{4}b^2.k.mx'.\sin(2mvt - 2mx').$$

Peculiarity of the form of the expression.

The first term of this expression is similar to those which we have found for the elevation when the displacement of the particles is small in comparison with the depth of the water. The second is entirely different, inasmuch as it contains the multiplier x' on the outside of the periodical function: it may be conceived to represent a wave whose magnitude continually increases as it travels along the canal.

(201.) To represent to the eye the form of the wave produced by the combination of the two terms, we have constructed the curve in figure 9. The horizontal line represents the level line of the mean height of water: the elevation or depression of the curve represents (on an enormously exaggerated scale) the elevation or depression above the mean height, given by the expression above. The value of x' is supposed to increase from the left to the right: on which supposition the quantity $mvt - mx'$, representing the phase of the wave, diminishes from the left to the right (mvt being constant).

(202.) To exhibit to the eye the law of the ascent and descent of the surface of the water at different points of the canal, the figures 10, 11, 12, and 13 are constructed. The first of these is intended for the point where the canal communicates with the sea: the others for points successively more and more distant from the sea. The horizontal line is used as a measure of time, or rather of the phase $mvt - mx'$: in which, for each station, x' is constant: the elevation or depression of the corresponding point of the curve represents the corresponding elevation or depression of the water above its mean height, as given by the expression above.

An inspection of these diagrams will suggest the following remarks:—

Peculiarity in the form of the wave.

(203.) When the wave leaves the open sea, its front slope and its rear slope are equal in length, and similar in form. But as it advances in the canal, its front slope becomes short and steep, and its rear slope becomes long and gentle. In advancing still further, this remarkable change takes place in the rear slope: it is not so steep in the middle as in the upper and the lower parts; at length it becomes horizontal at the middle; and, finally, slopes the opposite way, forming in fact two waves (figure 9).

(204.) At the station near the sea, (see figure 10,) the time occupied by the rise of the water is equal to the time occupied by the descent: at a station more removed from the sea (figure 11) the rise occupies a shorter time than the descent: the rise is steady and rapid throughout, but the descent begins rapid, then becomes more gentle, then becomes rapid again: at stations still farther from the sea, (figures 12 and 13,) the descent, after having begun rapid, is absolutely checked, or is even changed for a rise, to which another rapid descent succeeds: in this case there will be at that station two unequal tides corresponding to one tide at the mouth of the canal.

(205.) The greatest elevation and depression of the water are not much altered from one station to another.

Investigation of the duration of rise and fall of the water.

(206.) We may investigate the duration of the rise and fall in the following manner. The elevation of the water above its mean height, or $-bk\left\{\sin(mvt - mx') - \cos(mvt - mx').\frac{3}{2}bmx'.\sin(mvt - mx')\right\}$, may be put under the form $-bk\sin\left\{mvt - mx' - \frac{3}{2}bmx'.\sin(mvt - mx')\right\}$, considering the second term as small in comparison with the first. The phase of low water will be represented by giving to the sine its greatest positive value, or by making $mvt - mx' - \frac{3}{2}bmx'.\sin(mvt - mx') = \frac{\pi}{2}$. The first approximation (neglecting the second term) gives $mvt - mx' = \frac{\pi}{2}$, and $\sin(mvt - mx') = 1$. Substituting this in the second term, $mvt - mx' - \frac{3}{2}bmx' = \frac{\pi}{2}$: therefore

$$\text{at low water,} \quad t = \frac{1}{mv}\left\{\frac{\pi}{2} + mx' + \frac{3}{2}bmx'\right\}.$$

The next low water will be found by making $mvt - mx' - \frac{3}{2}bmx'.\sin(mvt - mx') = \frac{5\pi}{2}$; the next by making it $= \frac{9\pi}{2}$, &c.; and the corresponding values of t are $\frac{1}{mv}\left\{\frac{5\pi}{2} + mx' + \frac{3}{2}bmx'\right\}$, $\frac{1}{mv}\left\{\frac{9\pi}{2} + mx' + \frac{3}{2}bmx'\right\}$, &c. The phase of high water will be represented by giving to the sine its greatest negative value, or by making $mvt - mx' - \frac{3}{2}bmx'.\sin(mvt - mx') = \frac{3\pi}{2}$. The first approximation gives $mvt - mx' = \frac{3\pi}{2}$, $\sin mvt - mx = -1$. Substituting this in the second term, $mvt - mx' + \frac{3}{2}bmx' = \frac{3\pi}{2}$; therefore

$$\text{at high water,} \quad t = \frac{1}{mv}\left\{\frac{3\pi}{2} + mx' - \frac{3}{2}bmx'\right\}.$$

The successive high waters will be obtained by putting $\frac{7\pi}{2}$, $\frac{11\pi}{2}$, &c., in place of $\frac{3\pi}{2}$. Thus we have

At low water $t=\frac{1}{mv}\left\{\frac{\pi}{2}+mx'+\frac{3}{2}bmx'\right\}$

At the next high water $t=\frac{1}{mv}\left\{\frac{3\pi}{2}+mx'-\frac{3}{2}bmx'\right\}$

At the next low water $t=\frac{1}{mv}\left\{\frac{5\pi}{2}+mx'+\frac{3}{2}bmx'\right\}$

At the next high water $t=\frac{1}{mv}\left\{\frac{7\pi}{2}+mx'-\frac{3}{2}bmx'\right\}$

&c.

Interval from low water to high water $=\frac{1}{mv}\{\pi-3bmx'\}$

Interval from high water to low water $=\frac{1}{mv}\{\pi+3bmx'\}$

Excess of the latter above the former $=\frac{1}{mv}6bmx'=6b\frac{x'}{v}$.

As $v=\frac{n}{m}$, this is $6b\frac{mx'}{n}$.

Rise of the water occupies less time than its fall.

(207.) The fraction $\frac{x'}{v}$ is the time occupied by the tide-wave in passing from the open sea to the station under consideration. Thus we find,

Excess of the time of water falling above the time of water rising $=6b\times$ time occupied by the tide-wave in passing from the open sea to the station under consideration.

$$\text{Where}\quad b=\frac{\text{rise of tide above the mean state}}{\text{mean depth of water}}.$$

Thus in any part of the canal far from the sea, the times of high water and of low water, and the interval between them, will on different days depend on the extent through which the surface of the water oscillates up and down, or upon the magnitude of the whole rise of tide. And in places on the canal at different distances from the sea, the inequality of the times of water rising and water falling will, on the same day, depend upon the distance of the places from the sea.

(208.) Since the high water occurs, in the place whose distance from the sea is x', at the time $\frac{1}{mv}\left\{\frac{3\pi}{2}+mx'-\frac{3}{2}bmx'\right\}$, it will occur, in the place whose distance is $x'+x_{,}$, at the time

$$\frac{1}{mv}\left\{\frac{3\pi}{2}+m.\overline{x'+x_{,}}-\frac{3}{2}bm.\overline{x'+x_{,}}\right\},$$

and therefore the time occupied by the phase of high water in describing the space $x_{,}$ will be $\frac{1}{mv}\left\{mx_{,}-\frac{3}{2}bmx_{,}\right\}$ $=\frac{x_{,}}{v}\left(1-\frac{3b}{2}\right)=\frac{x_{,}}{v\left(1+\frac{3b}{2}\right)}$ nearly; therefore the phase of high water has travelled along the canal with the velocity $v\left(1+\frac{3b}{2}\right)=\sqrt{gk}\times\left(1+\frac{3b}{2}\right)=\sqrt{\{gk(1+3b)\}}$ nearly. The velocity with which a shallow wave of great length would travel along the surface of water, whose depth $=$ depth here at high water, would, by (172.), be $\sqrt{g\times\text{depth at high water}}=\sqrt{g\times k(1+b)}$. Consequently, the phase of high water travels along the canal with a velocity greater than that of a shallow wave on water of the same depth as the high water. In like manner, the phase of low water travels along the canal with the velocity $\sqrt{\{gk(1-3b)\}}$ nearly, which is less than that of a long shallow wave on water of the same depth as the low water. The following theorem will be easily remembered. If D_2 be the depth at low water, D_3 that at high water, and if D_1, D_2, D_3, D_4, are in arithmetical progression; then the phase of low water travels with the velocity due to the depth D_1, and the phase of high water with the velocity due to the depth D_4.

Simple rule for the velocity of the phases of high water and low water.

(209.) The actual velocity of the particles of the water, or the velocity of the tide-stream, is represented by $\frac{dX}{dt}$. Observing that $X=a.\cos(mvt-mx)-\frac{3}{8}a^2m^2x.\cos(2mvt-2mx)+\frac{5}{16}ma^2.\sin(2mvt-2mx)$, we have

$$\frac{dX}{dt}=amv\left\{-\sin(mvt-mx)+\frac{3}{4}am^2x.\sin(2mvt-2mx)+\frac{5}{8}ma.\cos(2mvt-2mx)\right\}.$$

This is the velocity of the particles whose original ordinate was x: if for x, as in (199.), we put $x'-a\cos(mvt-mx')$, the expression for the velocity of the particles of water which are passing the place whose ordinate measured on the canal-bank is x', will become

$$amv\left\{-\sin(mvt-mx')-\frac{ma}{2}+\frac{ma}{8}\cos(2mvt-2mx')+\frac{3}{4}am^2x'\sin(2mvt-2mx')\right\}.$$

At high water, $mvt-mx'=\frac{3\pi}{2}-\frac{3}{2}bmx'$, $\sin(mvt-mx')=-1$ nearly, $2mvt-2mx'=3\pi$ nearly, $\sin(2mvt-2mx')=0$, $\cos(2mvt-2mx')=-1$, and the expression for the velocity is

$$amv\left\{1-\frac{ma}{2}-\frac{ma}{8}\right\}=bv\left\{1-\frac{5b}{8}\right\}.$$

At low water, $mvt-mx'=\frac{\pi}{2}+\frac{3}{2}bmx'$, $\sin(mvt-mx')=1$, $\sin(2mvt-2mx')=0$, $\cos(2mvt-2mx')=-1$, and

Velocity of ebb-stream greater than that of flow-stream.

the expression for the velocity is $amv\left\{-1-\frac{ma}{2}-\frac{ma}{8}\right\}=$

$$-amv\left\{1+\frac{ma}{2}+\frac{ma}{8}\right\}=-bv\left\{1+\frac{5b}{8}\right\}.$$

These are respectively the same (very nearly) as the greatest velocities of the water up and down the canal: hence the greatest velocity of the tide-stream downwards exceeds the greatest velocity of the tide-stream upwards.

(210.) If we wish to proceed with a third approximation to the value of X, we must use the value already found, namely,

$$X=a\cos\overline{mvt-mx}+\frac{5ma^2}{16}\sin\overline{2mvt-2mx}-\frac{3m^2a^2}{8}x\cos\overline{2mvt-2mx};$$

in which the two last terms are to be regarded as small quantities of the second order. We must then substitute this (having due regard to the orders of quantities) in the right-hand side of the equation,

$$4v^2.\frac{d^2X}{du\,dw}=\frac{d^2X}{dt^2}-v^2\frac{d^2X}{dx^2}=v^2\frac{d^2X}{dx^2}\times\left\{-3\frac{dX}{dx}+6\left(\frac{dX}{dx}\right)^2\right\};$$

in which the right-hand side of the equation is to be expressed in terms of u and w; and, solving it, we obtain a value of X, to which (as before) an arbitrary term $\phi(vt-x)$ is to be attached. This arbitrary term can only be of the third order, inasmuch as the last approximation comprehended every term of the second order. From this expression for X, that for V is obtained by substitution in the equation

$$V=k\left(1-\frac{dX}{dx}+\left(\frac{dX}{dx}\right)^2-\left(\frac{dX}{dx}\right)^3\right).$$

Then, to adapt our expression for the elevation to a fixed point on the canal-bank, we must solve the equation $x+X=x'$, including terms of the second order: this gives

$$x=x'-a.\cos\overline{mvt-mx'}+\frac{3}{16}ma^2.\sin\overline{2mvt-2mx'}+\frac{3}{8}m^2a^2x'.\cos\overline{2mvt-2mx'}.$$

This must be substituted in every part of the expression for V; and the arbitrary function $\phi(vt-x)$ must be so determined as to make the expression $=k\left(1-ma.\sin\overline{mvt-mx'}\right)$ at the mouth of the canal, or when $x'=0$. The expression finally obtained is this; putting b for ma,

Solution to third approximation.

$$V=k\left\{1-b.\sin\overline{mvt-mx'}+\left(\frac{3}{4}b^2.\sin\overline{2mvt-2mx'}+\frac{33}{32}b^3.\cos\overline{mvt-mx'}-\frac{21}{32}b^3.\cos\overline{3mvt-3mx'}\right)mx'\right.$$
$$\left.+\left(\frac{9}{32}b^3.\sin\overline{mvt-mx'}-\frac{27}{32}b^3.\sin\overline{3mvt-3mx'}\right)m^2x'^2\right\}.$$

In figures (14) and (15) we have represented the course of the waves up a channel on two suppositions: the first supposing $b=\frac{1}{3}$, the second supposing $b=\frac{1}{6}$. We shall leave to the reader the task of discussing the results of this approximation, or of proceeding with further approximations. That which we have obtained will be found very important in the explanation of some peculiar cases of tides.

(211.) On account of the great importance of this problem in applications to the tides, we shall examine another modification of it.

Problem.—To investigate the motion of the tide-wave under the same circumstances, when the water of the canal is supposed also to have a current-flow (independent of fluctuations of tide) towards the sea.

Investigation when there is a current-flow in the river.

(212.) The investigation of the equation of the last problem includes this case, and the differential equation, therefore, will be the same, namely,

$$\frac{d^2X}{dt^2}-v^2\frac{d^2X}{dx^2}=v^2\frac{d^2X}{dx^2}\times\left\{-3\frac{dX}{dx}+6\left(\frac{dX}{dx}\right)^2-\&c.\right\}.$$

For a first approximation, $\frac{d^2X}{dt^2}-v^2\frac{d^2X}{dx^2}=0$; the solution of which is $X=\phi(vt-x)+\psi(vt+x)$. Now it will not be sufficient to take $X=a\cos(mvt-mx)$, because this formula will not express the current-flow: but that circumstance will be expressed by the following assumption:—

Solution to first approximation.

$$X=a\cos(mvt-mx)-\frac{e}{2v}(vt+x)-\frac{e}{2v}(vt-x),$$

or

$$X=a\cos(mvt-mx)-et;$$

where e represents the mean velocity of the current-flow towards the sea.

Solution to second approximation.

(213.) For the second approximation we find the same equation as before (198.), and the general solution will be the same as that of (198.), namely,

$$X=\phi(vt-x)+\psi(vt+x)-\frac{3}{16}a^2m^2(vt+x)\cos(2mvt-2mx).$$

But for the arbitrary functions we cannot adopt the same form as in (198.): first, because, as we have already seen, the principal term of X must have the form $a\cos(mvt-mx)-et$: secondly, because, as in (199.), the term $x.\cos(2mvt-2mx)$ will introduce a term $x.\sin(2mvt-2mx)$ into the expression for V; and, as x is the original co-ordinate of the particles, and as these particles (from the flow of the current) will at length come to the mouth of the canal or to the sea, it would follow that in the sea, after the lapse of a certain time, we shall have an oscillation expressed by $\sin(2mvt-2mx)$, which is inadmissible. The latter fault, it is easily seen, will be remedied by introducing the proper multiple of $t.\cos(2mvt-2mx)$. This can be done by means of the arbitrary functions, since $f\times(vt-x)\times\cos(2mvt-2mx)$ is a function of $vt-x$. Adding, also, the arbitrary terms in the solution of (198.), we have

$$\begin{aligned}X=a\cos(mvt-mx)-et-\frac{3}{8}a^2m^2.x.\cos(2mvt-2mx)&\\+ca^2.\cos(2mvt-2mx)&\\+c'a^2.\sin(2mvt-2mx)&\\+f\times(vt-x)\times\cos(2mvt-2mx).&\end{aligned}$$

(214.) From this expression we obtain the following value of $\frac{dX}{dx}$:

$$\begin{aligned}am.\sin(mvt-mx)+\left\{2ca^2m+2fmvt-\left(2fm+\frac{3}{4}a^2m^3\right)x\right\}\sin(2mvt-2mx)&\\-\left\{2c'a^2m+f+\frac{3}{8}a^2m^2\right\}\cos(2mvt-2mx);&\end{aligned}$$

and substituting this in the expression $V=\frac{k}{1+\frac{dX}{dx}}$, we find

$$V=k\left\{\begin{aligned}&1-am\sin(mvt-mx)+\frac{a^2m^2}{2}\\&\qquad-\left\{2ca^2m+2fmvt-\left(2fm+\frac{3}{4}a^2m^3\right)x\right\}\sin(2mvt-2mx)\\&\qquad+\left\{2c'a^2m+f+\frac{3}{8}a^2m^2-\frac{a^2m^2}{2}\right\}\cos(2mvt-2mx).\end{aligned}\right\}$$

But this expression gives the height of the water at the place of those particles whose original ordinate was x. If we wish to find the height of the water at the place whose ordinate, measured along the bank of the canal, is x', we must ascertain the value of the original ordinate x of the particles whose ordinate at the instant in question is x', and must substitute that value of x in the expression. The first step, then, is to make $x+X=x'$. Now X, by the expressions obtained, $=a\cos(mvt-mx)-et$ nearly: and the equation is

$$x+a.\cos(mvt-mx)-et=x'.$$

The first approximate solution is $x-et=x'$, whence $mx=mx'+met$. Substituting this in the small term, the equation becomes

$$x+a.\cos\left(\overline{mv-me}.t-mx'\right)-et=x',$$

or

$$x=x'+et-a.\cos\left(\overline{mv-me}.t-mx'\right).$$

This degree of approximation is sufficient. Substituting this expression for x in the second term of the formula for V, and substituting $x'+et$ for x in the remaining terms of the formula for V, we find

$$V=k\left\{\begin{array}{l}1-am.\sin\left(\overline{v-e}.mt-mx'\right)+\left\{-2ca^2m+\left(-2fm.\overline{v-e}+\frac{3}{4}a^2m^3e\right)t+\left(2fm+\frac{3}{4}a^2m^3\right)x'\right\}\sin\left(2.\overline{v-e}.mt-2mx'\right)\\ \qquad\qquad+\left\{2c'a^2m+f-\frac{5}{8}a^2m^2\right\}\cos\left(2.\overline{v-e}.mt-2mx'\right).\end{array}\right\}$$

(215.) At the sea $x'=0$. Now we assume that at the sea the oscillation follows the simple law of $-kam.\sin nt$, or $-kam.\sin\left(\overline{v-e}.mt\right)$. Equating to zero the terms which remain in addition to that term when $x'=0$, we find: $-2ca^2m=0$; $-2fm.\overline{v-e}+\frac{3}{4}a^2m^3e=0$, or $f=\frac{3}{8}a^2m^2.\frac{e}{v-e}$; $2c'a^2m+f-\frac{5}{8}a^2m^2=0$.

Expression for tidal elevation.

Substituting the value of f, we now find

$$V=k\left\{1-am.\sin\left(\overline{v-e}\,mt-mx'\right)+\frac{3}{4}a^2m^3\frac{v}{v-e}.x'.\sin\left(2.\overline{v-e}.mt-2mx'\right)\right\};$$

or, putting $am=b$, the expression for the elevation of the water above its mean height is,

$$K=-bk.\sin\left(\overline{v-e}.mt-mx'\right)+\frac{3}{4}b^2k.\frac{v}{v-e}.mx'.\sin\left(2.\overline{v-e}.mt-2mx'\right).$$

(216.) We might proceed in the discussion of this expression and of that for X in the same manner as in (201.) &c. The only point, however, to which we shall attend here is the times of high water and low water. The expression just found may be put under the form

Investigation of the duration of rise and fall of the water.

$$-bk\left\{\sin\left(\overline{v-e}.mt-mx'\right)-\cos\left(\overline{v-e}.mt-mx'\right)\frac{3}{2}b.\frac{v}{v-e}mx'.\sin\left(\overline{v-e}.mt-mx'\right)\right\}$$

$$\text{or}\quad -bk\sin\left\{\overline{v-e}.mt-mx'-\frac{3}{2}b.\frac{v}{v-e}mx'.\sin\left(\overline{v-e}.mt-mx'\right)\right\}.$$

For low water we must give to the sine its greatest positive value, or must make the arc $=\frac{\pi}{2}$, or $\frac{5\pi}{2}$, or $\frac{9\pi}{2}$, &c. Adopting $\frac{\pi}{2}$, we have

$$\overline{v-e}.mt-mx'-\frac{3}{2}b.\frac{v}{v-e}.mx'.\sin\left(\overline{v-e}.mt-mx'\right)=\frac{\pi}{2}.$$

A first approximation is $\overline{v-e}.mt-mx'=\frac{\pi}{2}$, $\sin\left(\overline{v-e}.mt-mx'\right)=1$. Substituting in the second term,

$$\overline{v-e}.mt-mx'-\frac{3}{2}b.\frac{v}{v-e}.mx'=\frac{\pi}{2};$$

from which

$$t=\frac{1}{(v-e)m}\left\{\frac{\pi}{2}+mx'+\frac{3}{2}b.\frac{v}{v-e}.mx'\right\}.$$

Rise of tide occupies less time than the fall.

Proceeding in the same manner for high water, and taking different multiples of $\frac{\pi}{2}$, we find the following times.

At low water $$t=\frac{1}{(v-e)m}\left\{\frac{\pi}{2}+mx'+\frac{3}{2}b.\frac{v}{v-e}.mx'\right\}.$$

At the next high water $$t=\frac{1}{(v-e)m}\left\{\frac{3\pi}{2}+mx'-\frac{3}{2}b.\frac{v}{v-e}mx'\right\}.$$

At the next low water $$t=\frac{1}{(v-e)m}\left\{\frac{5\pi}{2}+mx'+\frac{3}{2}b.\frac{v}{v-e}mx'\right\}.$$

At the next high water $$t=\frac{1}{(v-e)m}\left\{\frac{7\pi}{2}+mx'-\frac{3}{2}b.\frac{v}{v-e}mx'\right\}.$$

&c.

Interval from low water to high water $$=\frac{1}{(v-e)m}\left\{\pi-3b\frac{v}{v-e}mx'\right\}$$

Interval from high water to low water $$=\frac{1}{(v-e)m}\left\{\pi+3b\frac{v}{v-e}mx'\right\}$$

Excess of the latter above the former $$=6bx'\frac{v}{(v-e)^2}.$$

As $v-e=\frac{n}{m}$, this is $$6b.\frac{m^2}{n^2}\left(\frac{n}{m}+e\right)x'=6bx'\left(\frac{m}{n}+e\frac{m^2}{n^2}\right).$$

This excess is greater than the excess when there is no current, in the proportion of $1+\frac{em}{n}$ to 1.

(217.) The preceding investigations suppose that the depth of the canal is uniform in its cross section. In the case of a wave of great length, as the tide-wave, we may, however, apply a satisfactory investigation to the motion of the wave along a canal of uniform section of any form.

Problem.—The section of the canal is defined by the equation $z=\phi(y)$, z being a horizontal co-ordinate: to find the equations for the motion of a long wave.

Investigation for long waves in a canal whose section is invariable but of any form.

(218.) Let $u=\psi(y)$ be the area of the section up to the height y, so that $\frac{du}{dy}=z$: let X be the horizontal displacement, in the direction of the canal's length, of the particles whose co-ordinate measured along the canal was x; V the present elevation of that part of the water. Then, as in (194.), the horizontal space which was h has now become $h\left(1+\frac{dX}{dx}\right)$, and the area of section which was $\psi(k)$ is now $\psi(V)$, and therefore the volume which was expressed by $h.\psi(k)$ is now expressed by $h\left(1+\frac{dX}{dx}\right)\psi(V)$. Making these equal,

$$\psi(V)=\frac{\psi(k)}{1+\frac{dX}{dx}}.$$

This is the equation of continuity.

(219.) The pressure tending to push forward the water included between the two particles whose horizontal co-ordinates were x and $x+h'$, and whose horizontal co-ordinates are now $x+X$ and $x+X+\left(1+\frac{dX}{dx}\right)h'$, will, as in (195.) be the difference of the pressures caused by two vertical columns whose heights are $V-y$ and $V+\frac{dV}{dx}h'-y$ respectively. Hence, as in (195.), we find

$$\frac{d^2X}{dt^2}=-g.\frac{dV}{dx}.\frac{1}{1+\frac{dX}{dx}}.$$

To eliminate $\frac{dV}{dx}$, we must differentiate the equation of continuity found above, from which we obtain

$$\psi'(V).\frac{dV}{dx}=\frac{-\psi(k)}{\left(1+\frac{dX}{dx}\right)^2}.\frac{d^2X}{dx^2};$$

substituting from this, we have

$$\frac{d^2X}{dt^2}=\frac{g\psi(k)}{\psi'(V)}.\frac{\frac{d^2X}{dx^2}}{\left(1+\frac{dX}{dx}\right)^3},$$

an equation which may be solved by successive substitution.

(220.) The first approximation will be made by considering V in the factor as equal to k, and neglecting

Solution to first approximation.

$\frac{dX}{dx}$. This gives $\frac{d^2X}{dt^2}=\frac{g\,\psi(k)}{\psi'(k)}\cdot\frac{d^2X}{dx^2}$. Let $k'=\frac{\psi(k)}{\psi'(k)}$, $v'^2=gk'$: then $\frac{d^2X}{dt^2}=v'^2\frac{d^2X}{dx^2}$; of which the solution is $X=\chi(v't-x)+\omega(v't+x)$. This expression denotes that the waves travel with the same velocity v' or $\sqrt{gk'}$, as if the depth of the canal were uniform and equal to $\frac{\psi(k)}{\psi'(k)}$ or $\frac{\psi(k)}{\phi(k)}$. For instance, if the section of the canal were a triangle, $\phi(y)=z=ay$: $\psi(y)=\int_y\phi(y)=\frac{ay^2}{2}$: therefore $\frac{\psi(k)}{\phi(k)}=\frac{\frac{ak^2}{2}}{ak}=\frac{k}{2}$, and the velocity would be that due to a canal of uniform depth equal to half the greatest depth of the triangular canal. If the section were a parabola, $\phi(y)=z=\sqrt{ay}$: $\psi(y)=\frac{2}{3}\sqrt{ay^3}$: $\frac{\psi(k)}{\phi(k)}=\frac{2}{3}\cdot\frac{\sqrt{ak^3}}{\sqrt{ak}}=\frac{2k}{3}$, and the velocity would be that due to a canal of uniform depth equal to two-thirds of the greatest depth of the parabolic canal.

Equation to second approximation.

(221.) For a second approximation, we must expand the equation $\psi(V)=\frac{\psi(k)}{1+\frac{dX}{dx}}$ to the first power of small quantities: this gives $\psi(k)+\psi'(k).(V-k)=\psi(k)-\psi(k)\frac{dX}{dx}$,

whence
$$V-k=\frac{-\psi(k)}{\psi'(k)}\cdot\frac{dX}{dx},$$

and $\psi'(V)$, or $\psi'(k+V-k)=\psi'(k)+\psi''(k).(V-k)=\psi'(k)-\frac{\psi(k).\psi''(k)}{\psi'(k)}\cdot\frac{dX}{dx}$:

therefore
$$\frac{g\psi(k)}{\psi'(V)}=\frac{g\psi(k)}{\psi'(k)}\cdot\left\{1+\frac{\psi(k).\psi''(k)}{\{\psi'(k)\}^2}\cdot\frac{dX}{dx}\right\};$$

and the equation becomes
$$\frac{d^2X}{dt^2}=\frac{g\psi(k)}{\psi'(k)}\cdot\left\{1-\frac{3\{\psi'(k)\}^2-\psi(k).\psi''(k)}{\{\psi'(k)\}^2}\cdot\frac{dX}{dx}\right\}\cdot\frac{d^2X}{dx^2},$$

which is to be solved in the same manner as in (198.), &c.

Limitations to the application of this solution.

(222.) The preceding solution, it is plain, depends on the assumption that the horizontal motion in the direction of z is insignificant in comparison with that in the direction of x. And this consideration points out the limitations within which the solution will apply. It will certainly apply when the sides of the canal at and near the surface of the water are so steep (say, for instance, inclined at an angle of 45° to the vertical) that the motion in the direction of z does not much exceed the vertical motion. It will certainly not apply when the shore is so flat that the motion in the direction of z greatly exceeds the vertical motion and is at all comparable with the motion in the direction of x.

Addition of solutions does not apply here.

(223.) Before closing this subsection, we must call the reader's attention to the circumstance that the addition of solutions, treated of in (186.), and which holds in all cases of waves where the motion of the particles is extremely small, does not hold here. For, if we have two functions X′ and X″, each of which separately satisfies one of the equations,

$$\frac{d^2X'}{dt^2}-v^2\frac{d^2X'}{dx^2}=v^2\frac{d^2X'}{dx^2}\times\left\{-3\frac{dX'}{dx}+,\ \&c.\right\}$$
$$\frac{d^2X''}{dt^2}-v^2\frac{d^2X''}{dx^2}=v^2\frac{d^2X''}{dx^2}\times\left\{-3\frac{dX''}{dx}+,\ \&c.\right\}$$

the sum of these functions will not satisfy the similar equation,

$$\frac{d^2(X'+X'')}{dt^2}-v^2\frac{d^2(X'+X'')}{dx^2}=v^2\frac{d^2(X'+X'')}{dx^2}\times\left\{-3\frac{d(X'+X'')}{dx}+,\ \&c.\right\}$$

as will be evident on adding together the two equations.

Subsection 4.—Theory of Waves when the Water is under the action of Horizontal and Vertical Forces.

(224.) The general equations applicable to water under the action of forces (149.) are

$$Y=\Xi.\frac{d\eta}{dx}-\int_y\frac{dX}{dx}\ (\eta\text{ to }y)$$

Tides and Waves.

$$\frac{d^2X}{dt^2}=F+\frac{d}{dx}\left\{-g'(k+K-y)-\int_y \frac{d^2Y}{dt^2}\,(y \text{ to } k)\right\},$$

General equations when there is external force.

where F is the extraneous force acting in an horizontal direction, and g' is gravity increased by the extraneous force acting in the vertical direction. If there be no extraneous vertical force, the second equation becomes

$$\frac{d^2X}{dt^2}=F+\frac{d}{dx}\left\{-gK-\int_y \frac{d^2Y}{dt^2}\,(y \text{ to } k)\right\}.$$

Before entering upon the legitimate objects of this subsection, we will apply these equations to the solution of two or three problems which would, at first sight, seem to be unconnected with them.

(225.) Hitherto we have assumed in every part of our investigation that there is upon the surface of the water an unlimited succession of waves. We shall now proceed to consider the case of a single wave.

Problem.—To ascertain the conditions under which it is possible that a single wave can travel along a canal.

Investigation for motion of a solitary wave.

(226.) By a moving wave, we mean in all cases (till we shall make new suppositions) a displacement of the particles, of such a nature that, upon examining the state of particles which are at a greater distance in the direction of x, and increasing the time by a quantity proportionate to that increase of distance, the displacement of the new particles at that later time will be found the same as the displacement of the old particles at the earlier time. It follows, therefore, that in all cases, whether there be a single wave or an indefinite succession of waves, the displacement must be represented by a function of $vt-x$. Yet any ordinary function of $vt-x$ will not fulfil our object, inasmuch as any ordinary function, though it may make the displacement $=0$ for particular values of $vt-x$, will not make the displacement $=0$ for all the values of $vt-x$ corresponding to the values of x preceding and following that part of the surface at which alone the wave is supposed to have a real existence at any instant of time t. We must adopt for our purpose a *discontinuous* function; that is (putting, for convenience, $vt-x=z$), we must suppose that for all values of z up to a certain limit, the value of X is 0; that from that limiting value of z up to another certain limit, the value of X will be expressed by a certain function of z, whose form is given: that from that second limiting value to a third, the value of X will be expressed by another certain function of z: and so on: and that for values of z exceeding that value which corresponds to the termination of the wave, the value of X will be constantly 0, or equal to some assigned quantity. This supposition corresponds exactly to the supposition that the surface of the water is perfectly level up to a certain point, and that then there exists a wave whose outline is determined by uniting portions of different curves, and that after that the water is again level. There is no objection whatever to our making such a supposition, provided that it be so framed as to satisfy the conditions which are evidently implied in forming our equations for the wave-motion.

Discontinuous function may be used for a single wave.

(227.) To simplify our language, we will suppose that only one function of z (which we will call the *wave-function*) is adopted to express the value of X between the values $z=0$, $z=a$: that for values of z less than 0, X is always $=0$: and that for values of z greater than a, X is always $=b$. (This will denote that the particles of water are, as it were, carried through the space b by the passage of the wave and then deposited.) Upon examining the equations (224.) it will be seen that Y depends on $\frac{dX}{dx}$, and (as the integration is with regard to y only) will be a multiple of $\frac{dX}{dx}$: that therefore $\frac{d^2Y}{dt^2}$, and its integral with respect to y which occurs in the second equation, will be a multiple of $\frac{d^3X}{dx\,dt^2}$: and, considering X as a function of $vt-x$, it is easily seen that $\frac{d^3X}{dx\,dt^2}=-v^2\frac{d^3X}{dz^3}$: and therefore its differential coefficient depends on $\frac{d^4X}{dz^4}$. Consequently our equations involve all the differential coefficients of X with regard to z, to the fourth inclusive. We will now examine the restrictions under which this number of differential coefficients places our assumptions for the form of X: they depend intimately on the way in which we conceive the differential coefficients to be formed.

(228.) In physical investigations there is but one definition of the differential coefficient which can be applied, namely, *the limiting value of the quotient formed by dividing the increment of the function by the increment of the independent variable.* If the reader will turn to the investigations of (144.), &c., he will see that this principle is adopted throughout; in estimating the sides of the small parallelogram by which the equation of continuity is formed; in estimating the pressure depending on the vertical column of fluid; and in estimating the motion which it will produce in the horizontal column of fluid. Taking this definition, then, it is clear, in the first place, that algebraic continuity in the form of the function is unnecessary: but, in the second place, it is clear that at these values of z where different forms of the function unite, there must be no *sudden* change in the value of X: for, if there were a sudden change, then at that point the value of $\frac{dX}{dz}$ (in consequence of the mode of forming the differential coefficient just described) would be infinite. In fact $\frac{dX}{dz}$ would be the limiting

The differential coefficients to a certain order must vanish at the extremities of the wave.

value of $\frac{\delta X}{\delta z}$, where δX had a finite value even when δz was indefiuitely small: this would lead to suppositions of infinite forces, &c., such as were not contemplated at all in our investigation. There must, therefore, be no sudden change in the values of X at the beginning and the end of our wave-function. In like manner there must be no sudden change in the value of $\frac{dX}{dz}$ at the beginning and end of the wave-function, as such sudden change would make the values of $\frac{d^2X}{dz^2}$ infinite. In like manner there must be no sudden change in the values of $\frac{d^2X}{dz^2}$ and $\frac{d^3X}{dz^3}$. Then, as the equations of (224.) hold equally for still water, and for water in wave-motion, and as there is to be no sudden change in the values of the first and second and third differential coefficients, it follows also that there must be no sudden change in the value of the fourth. If, however, we are willing to suppose the sudden introduction of a finite force at a particular point of the wave, we may dispense with the last condition.

Forms of function which satisfy these conditions.

(229.) Now for the still water which precedes and follows the wave, all the differential coefficients are 0. Hence we must have,

At the beginning of the wave-function, or when $z=0$,

$$X=0, \quad \frac{dX}{dz}=0, \quad \frac{d^2X}{dz^2}=0, \quad \frac{d^3X}{dz^3}=0, \quad \frac{d^4X}{dz^4}=0.$$

At the end of the wave-function, or when $z=a$,

$$X \text{ must } =b, \quad \frac{dX}{dz}=0, \quad \frac{d^2X}{dz^2}=0, \quad \frac{d^3X}{dz^3}=0, \quad \frac{d^4X}{dz^4}=0.$$

The higher orders of differential coefficients may have any values whatever.

(230.) There is no difficulty in finding forms for X which will satisfy these conditions. For instance, if we take

$$X=\frac{630\,b}{a^9}\left\{\frac{1}{5}a^4z^5-\frac{2}{3}a^3z^6+\frac{6}{7}a^2z^7-\frac{1}{2}az^8+\frac{1}{9}z^9\right\};$$

then, on making $z=0$, X will $=0$: and, on making $z=a$, X will $=b$. The value of $\frac{dX}{dz}$ is $\frac{630\,b}{a^9}\cdot z^4.(a-z)^4$; and this quantity, and its three next differential coefficients, vanish when $z=0$ or $z=a$.

(231.) Similarly, if we had chosen to assume that for values of z greater than a, X should $=0$, that condition, with all the others, would be satisfied by the assumption for the wave-function $X=c.z^5.(a-z)^5$.

(232.) It may, however, be more convenient to assume a form depending on sines and cosines. Thus, suppose the condition to be that all particles resume, after the passing of the wave, the same place which they had before its approach, or that X shall $=0$ for all values of $z<0$, and for all $>a$. It is easily seen that the condition that X, $\frac{dX}{dz}$, $\frac{d^2X}{dz^2}$, $\frac{d^3X}{dz^3}$, $\frac{d^4X}{dz^4}$ shall $=0$ for $z=0$ and $z=a$, will be satisfied by the assumption $X=\sin^5\frac{\pi z}{a}$; or by any higher power of the sine; or by $\sin^5\frac{\pi z}{a}$ increased by any number of such quantities as $\sin^5\frac{c\pi(z+e)}{a}$, where c may be any number (whole or fractional) greater than 1, and where the argument $\frac{c\pi(z+e)}{a}$ may be carried through as many whole multiples of π as we please, provided that the first value of z be >0, and the last $<a$. (This amounts to the same as supposing that any number of short waves, possessing the characteristic property in regard to the differential coefficients at their beginnings and ends, are piled upon the longer wave.) But if the condition is to be, that the particles are to be removed to the distance b and left there, it will be satisfied by the assumption $X=\frac{8b}{3a}\int_z \sin^4\frac{\pi z}{a}=\frac{2b}{3\pi}\left\{\frac{3}{2}\cdot\frac{\pi z}{a}-\sin\frac{2\pi z}{a}+\frac{1}{8}\sin\frac{4\pi z}{a}\right\}$. For this makes $X=0$ when $z=0$, and $X=b$ when $z=a$; and it makes $\frac{dX}{dz}=0$, $\frac{d^2X}{dz^2}=0$, $\frac{d^3X}{dz^3}=0$, $\frac{d^4X}{dz^4}=0$, for $z=0$ and $z=a$. A higher power of the sine might have been taken; and the function might have been increased by any number of the supplementary functions mentioned above. Thus a single wave of any degree of complexity might be produced., We shall, however, for simplicity, confine ourselves to the simple form

$$X=\frac{8b}{3a}\int_z \sin^4\frac{\pi z}{a}.$$

(233.) But we have not yet examined whether these forms of wave are consistent in all respects with the equations of wave-motion. For this purpose we must substitute the assumed value of X in the equations

$$Y = -\int_y \frac{dX}{dx}(0 \text{ to } y)$$

$$\frac{d^2X}{dt^2} = F + \frac{d}{dx}\left\{-gK - \int_y \frac{d^2Y}{dt^2}(y \text{ to } k)\right\};$$

and thereby ascertain whether any force F is necessary to maintain the particles of water in the assumed state of movement. Now taking the last assumption, and putting $vt-x$ for z; and putting $\phi''(y)$ for the factor depending on y, $\left(\text{it being understood that at the surface, or when } y=k,\ \phi''(k)=\frac{2b}{3\pi}\right)$, where $\phi''(y)$ is conceived to be the second derived function of some function $\phi(y)$, we have

$$X = \phi''(y).\left\{\frac{3\pi}{2a}(vt-x) - \sin\frac{2\pi}{a}(vt-x) + \frac{1}{8}\sin\frac{4\pi}{a}(vt-x)\right\}$$

$$-\frac{dX}{dx} = \phi''(y).\left\{\frac{3\pi}{2a} - \frac{2\pi}{a}.\cos\frac{2\pi}{a}(vt-x) + \frac{\pi}{2a}\cos\frac{4\pi}{a}(vt-x)\right\}$$

$$Y = \{\phi'(y)-\phi'(0)\}.\left\{\frac{3\pi}{2a} - \frac{2\pi}{a}.\cos\frac{2\pi}{a}(vt-x) + \frac{\pi}{2a}\cos\frac{4\pi}{a}(vt-x)\right\}$$

$$K = \{\phi'(k)-\phi'(0)\}.\left\{\frac{3\pi}{2a} - \frac{2\pi}{a}.\cos\frac{2\pi}{a}(vt-x) + \frac{\pi}{2a}\cos\frac{4\pi}{a}(vt-x)\right\}$$

$$\frac{d^2Y}{dt^2} = \{\phi'(y)-\phi'(0)\}.\left\{\frac{8\pi^3}{a^3}v^2.\cos\frac{2\pi}{a}(vt-x) - \frac{8\pi^3}{a^3}v^2.\cos\frac{4\pi}{a}(vt-x)\right\}$$

$$-\int_y \frac{d^2Y}{dt^2}(y \text{ to } k) = \left\{\phi(y)-\phi(k)-\overline{y-k}.\phi'(0)\right\}.\left\{\frac{8\pi^3}{a^3}v^2.\cos\frac{2\pi}{a}(vt-x) - \frac{8\pi^3}{a^3}v^2.\cos\frac{4\pi}{a}(vt-x)\right\}$$

$$\frac{d}{dx}\left\{-gK - \int_y \frac{d^2Y}{dt^2}(y \text{ to } k)\right\} = \left\{\frac{4\pi^2 g}{a^2}.\overline{\phi'(k)-\phi'(0)} + \frac{16\pi^4 v^2}{a^4}.\overline{\phi(y)-\varphi(k)-(y-k).\phi'(0)}\right\}\sin\frac{2\pi}{a}(vt-x)$$

$$+\left\{-\frac{2\pi^2 g}{a^2}.\overline{\phi'(k)-\phi'(0)} - \frac{32\pi^4 v^2}{a^4}\overline{\phi(y)-\phi(k)-(y-k).\phi'(0)}\right\}\sin\frac{4\pi}{a}(vt-x)$$

$$-\frac{d^2X}{dt^2} = -\phi''(y).\frac{4\pi^2v^2}{a^2}\sin\frac{2\pi}{a}(vt-x) + \phi''(y).\frac{2\pi^2v^2}{a^2}\sin\frac{4\pi}{a}(vt-x).$$

Expression for force which is necessary to maintain this wave.

The sum of the two last expressions, with sign changed, is the value of F, the horizontal force which must be applied to maintain this state of undulation.

(234.) It is evident that the value of F cannot generally be $=0$, since the different parts of the coefficients of $\sin\frac{2\pi}{a}(vt-x)$ and $\sin\frac{4\pi}{a}(vt-x)$ are not in the same proportion, and therefore those coefficients cannot vanish together. Therefore, in general, this discontinuous wave cannot exist without the application of force. But if the wave be long, so that the terms divided by a^4 may be neglected in comparison with those divided by a^2, F will $=0$ if $-\frac{2\pi^2 g}{a^2}\overline{\phi'(k)-\phi'(0)} + \frac{2\pi^2 v^2}{a^2}\phi''(y) = 0$. This implies that $\phi''(y)$ is constant and $=\frac{2b}{3\pi}$; therefore, $\phi'(y) = \frac{2b}{3\pi}y$, and $\phi'(k)-\phi'(0) = \frac{2b}{3\pi}k$; and the equation becomes $-\frac{2\pi^2 g}{a^2}k + \frac{2\pi^2 v^2}{a^2} = 0$, or $v^2 = gk$. The same thing would have been found to be true if the wave-function had consisted of any number of sines. Thus it appears, that a single discontinuous wave of any degree of complexity may travel on water without any force to maintain it, provided, in the first place, that it satisfies the conditions laid down with regard to the differential coefficients at its terminations, and in the next place, that the wave is so long that a succession of simple waves, each of that length, would travel sensibly with the velocity due to waves of infinite length.

When the wave is very long, no force is necessary.

(235.) If the single wave is moderately long, a small force will maintain it as a discontinuous wave: but if it be short, the force must be (in proportion to the various pressures acting on the water) considerable. In fact, each of the different terms in the wave-function represents a wave of different length; and, when the waves are short, each of these would tend to travel on with its own peculiar velocity, which velocities are very different for the different waves. But when the waves are long, the peculiar velocities are very nearly the same for the different waves.

In a subsequent article (410.), we shall give the theory of a single wave, acted on by any force, and travelling with a velocity different from that mentioned above.

(236.) We may proceed in the same manner for the discussion of the motion of a single wave of considerable depth and of great length, observing that the equation for that case is $\frac{d^2 X}{dt^2} = F + gk . \frac{\frac{d^2 X}{dx^2}}{\left(1 + \frac{dX}{dx}\right)^2}$.

(237.) Hitherto we have supposed the depth in every part of the canal to be the same. We shall now suppose that the depth is different at different points of the canal; the variation, however, being supposed to be gradual. We have already seen (157.), that the equations cannot be satisfied in this case: and our investigation, therefore, cannot be quite so satisfactory in its character as the investigations undertaken where the equations can be satisfied. Still we conceive that the following will be found sufficiently certain and accurate to enable us to judge with confidence of the effect of the variation of depth upon the general circumstances of the waves.

Depth of canal variable.

Problem.—The depth being supposed variable: to find what alteration takes place in the magnitude, length, and velocity of the waves, in passing from one part of the canal to another.

(238.) In our former investigations, in which the horizontal bottom of the canal was taken as the axis of x, we found that the horizontal disturbance X might be represented by a collection of terms, each of which is of the form $A . (\varepsilon^{my} + \varepsilon^{-my}) \cos (nt - mx)$, where m and n are connected by the equation $n^2 = mg . \frac{\varepsilon^{mk} - \varepsilon^{-mk}}{\varepsilon^{mk} + \varepsilon^{-mk}}$. If, instead of taking the bottom of the canal, we had taken some other horizontal line for the axis of x, and if the ordinate of the bottom of the canal had then been η, the expression for X would have been $A (\varepsilon^{m(y-\eta)} + \varepsilon^{m(\eta-y)}) \cos (nt - mx)$; and the equation connecting m and n would have been $n^2 = mg . \frac{\varepsilon^{m(k-\eta)} - \varepsilon^{m(\eta-k)}}{\varepsilon^{m(k-\eta)} + \varepsilon^{m(\eta-k)}}$. In this case, η is constant.

Assumption on which a plausible solution may be found.

Suppose now that in our canal of slowly varying depth there are, at different parts, portions of sensible length, whose depth is uniform through those lengths; then, through each of these lengths, the expression for X and the equation between n and m will have the same form as those above. It seems, then, not unreasonable to conjecture that the same form may apply to the parts of variable depth, or the parts where η is a function of x, and where, consequently, m will be a function of x, (for n, upon which the *period* of the waves depends, must be invariable through the whole extent of the disturbed water.) A must also be a function of x, whose form is yet to be determined. In regard to the term mx under the cosine, a necessity for change will be obvious. In a canal of uniform depth, mx represents the decrease of phase due to the space x, and, therefore, mh would represent the decrease of phase due to the small space h: if, then, (going upon the principle already announced,) we make the phase decrease for each small part of the canal of variable depth in the same manner as if that depth were continued uniform, we must not use mx for the decrease of the phase, but $\int_x m$. Let this integral $= M$: then our supposition will be

$$X = A . (\varepsilon^{m(y-\eta)} + \varepsilon^{m(\eta-y)}) \cos (nt - M)$$

$$n^2 = mg . \frac{\varepsilon^{m(k-\eta)} - \varepsilon^{m.(\eta-k)}}{\varepsilon^{m(k-\eta)} + \varepsilon^{m(\eta-k)}};$$

where η is a given function of x, m in consequence is implicitly a given function of x, $\frac{dM}{dx} = m$, and A is an unknown function of x, whose form is to be determined so as to satisfy as nearly as possible the equations of waves.

(239.) The equation of continuity is

$$Y = \mathfrak{X} . \frac{d\eta}{dx} - \int_y \frac{dX}{dx} \text{ (from } \eta \text{ to } y).$$

Now
$$\frac{dX}{dx} = \frac{dA}{dx} (\varepsilon^{m(y-\eta)} + \varepsilon^{m(\eta-y)}) \cos \overline{nt - M} + A \frac{dm}{dx} . (y - \eta)(\varepsilon^{m(y-\eta)} - \varepsilon^{m(\eta-y)}) \cos \overline{nt - M}$$
$$- Am \frac{d\eta}{dx} (\varepsilon^{m(y-\eta)} - \varepsilon^{m(\eta-y)}) \cos \overline{nt - M} + Am (\varepsilon^{m(y-\eta)} + \varepsilon^{m(\eta-y)}) \sin \overline{nt - M}.$$

Therefore $- \int_y \frac{dX}{dx}$ from η to y, or $+ \int_y \frac{dX}{dx}$ from y to η, is

$$- \frac{dA}{dx} \frac{1}{m} . (\varepsilon^{m(y-\eta)} - \varepsilon^{m(\eta-y)}) \cos \overline{nt - M} - A \frac{1}{m} . \frac{dm}{dx} . (y - \eta) (\varepsilon^{m(y-\eta)} + \varepsilon^{m(\eta-y)}) \cos \overline{nt - M}$$

$$+\mathrm{A}.\frac{1}{m^2}.\frac{dm}{dx}\left(\varepsilon^{m(y-\eta)}-\varepsilon^{m(\eta-y)}\right)\cos\overline{nt-\mathrm{M}}+\mathrm{A}\frac{d\eta}{dx}\left(\varepsilon^{m(y-\eta)}+\varepsilon^{m(\eta-y)}\right)\cos\overline{nt-\mathrm{M}}$$

$$-\mathrm{A}\left(\varepsilon^{m(y-\eta)}-\varepsilon^{m(\eta-y)}\right).\sin\overline{nt-\mathrm{M}}-2\mathrm{A}\frac{d\eta}{dx}\cos\overline{nt-\mathrm{M}}.$$

And
$$\Xi.\frac{d\eta}{dx}=2\mathrm{A}\frac{d\eta}{dx}.\cos\overline{nt-\mathrm{M}}.$$

Therefore
$$\mathrm{Y}=-\frac{d\mathrm{A}}{dx}.\frac{1}{m}\left(\varepsilon^{m(y-\eta)}-\varepsilon^{m(\eta-y)}\right).\cos\overline{nt-\mathrm{M}}-\mathrm{A}.\frac{1}{m}.\frac{dm}{dx}(y-\eta)\left(\varepsilon^{m(y-\eta)}+\varepsilon^{m(\eta-y)}\right)\cos\overline{nt-\mathrm{M}}$$

$$+\mathrm{A}\frac{1}{m^2}.\frac{dm}{dx}.\left(\varepsilon^{m(y-\eta)}-\varepsilon^{m(\eta-y)}\right).\cos\overline{nt-\mathrm{M}}+\mathrm{A}.\frac{d\eta}{dx}\left(\varepsilon^{m(y-\eta)}+\varepsilon^{m(\eta-y)}\right)\cos\overline{nt-\mathrm{M}}$$

$$-\mathrm{A}\left(\varepsilon^{m(y-\eta)}-\varepsilon^{m(\eta-y)}\right).\sin\overline{nt-\mathrm{M}};$$

or
$$\mathrm{Y}=-\frac{d}{dx}\left\{\frac{\mathrm{A}}{m}\left(\varepsilon^{m(y-\eta)}-\varepsilon^{m(\eta-y)}\right)\cos\overline{nt-\mathrm{M}}\right\}.$$

(240.) The equation of equal pressure is

$$\mathrm{F}=\frac{d^2\mathrm{X}}{dt^2}+\frac{d}{dx}\left\{g\mathrm{K}+\int_y\frac{d^2\mathrm{Y}}{dt^2}(y\text{ to }k)\right\}.$$

Now it is well known that, as x, y, and t, are independent of each other, the differentiation expressed by $\frac{d^2\mathrm{Y}}{dt^2}$ may be performed upon the quantity under the sign $\frac{d}{dx}$; and the integration with regard to y may also be performed on the quantity under the sign $\frac{d}{dx}$, provided that (as is the case here) the limits of the integral are independent of x. Thus we have

$$\frac{d^2\mathrm{Y}}{dt^2}=\frac{d}{dx}\left\{\frac{n^2\mathrm{A}}{m}\left(\varepsilon^{m(y-\eta)}-\varepsilon^{m(\eta-y)}\right)\cos\overline{nt-\mathrm{M}}\right\}$$

$$\int_y\frac{d^2\mathrm{Y}}{dt^2}(\text{generally})=\frac{d}{dx}\left\{\frac{n^2\mathrm{A}}{m^2}\left(\varepsilon^{m(y-\eta)}+\varepsilon^{m(\eta-y)}\right)\cos\overline{nt-\mathrm{M}}\right\}$$

$$\int_y\frac{d^2\mathrm{Y}}{dt^2}(y\text{ to }k)=-\frac{d}{dx}\left\{\frac{n^2\mathrm{A}}{m^2}\left(\varepsilon^{m(y-\eta)}+\varepsilon^{m(\eta-y)}\right)\cos\overline{nt-\mathrm{M}}\right\}$$
$$+\frac{d}{dx}\left\{\frac{n^2\mathrm{A}}{m^2}\left(\varepsilon^{m(k-\eta)}+\varepsilon^{m(\eta-k)}\right)\cos\overline{nt-\mathrm{M}}\right\}.$$

And
$$g\mathrm{K}=-\frac{d}{dx}\left\{\frac{g\mathrm{A}}{m}\left(\varepsilon^{m(k-\eta)}-\varepsilon^{m(\eta-k)}\right)\cos\overline{nt-\mathrm{M}}\right\}.$$

In adding these together, it will be observed, that the two last lines destroy each other, by virtue of the equation $n^2=mg\frac{\varepsilon^{m(k-\eta)}-\varepsilon^{m(\eta-k)}}{\varepsilon^{m(k-\eta)}+\varepsilon^{m(\eta-k)}}$. And as $\frac{d^2\mathrm{X}}{dt^2}=-n^2\mathrm{A}\left(\varepsilon^{m(y-\eta)}+\varepsilon^{m(\eta-y)}\right)\cos\overline{nt-\mathrm{M}}$, the expression for F becomes

$$\mathrm{F}=-n^2\mathrm{A}\left(\varepsilon^{m(y-\eta)}+\varepsilon^{m(\eta-y)}\right)\cos\overline{nt-\mathrm{M}}-\frac{d^2}{dx^2}\left\{\frac{n^2\mathrm{A}}{m^2}\left(\varepsilon^{m(y-\eta)}+\varepsilon^{m(\eta-y)}\right)\cos\overline{nt-\mathrm{M}}\right\}.$$

Expression for force necessary to maintain this motion.

(241.) To facilitate the differentiation of the last term, we will remark, that the alteration of depth is supposed to be gradual, so that $\frac{d\eta}{dx}$ is small, and therefore $\frac{dm}{dx}$ and $\frac{d\mathrm{A}}{dx}$ which depend on it are small, and therefore their powers and products and the second differential coefficients will be extremely small, and may be neglected. If then for the moment we make $\frac{n^2\mathrm{A}}{m^2}\left(\varepsilon^{m(y-\eta)}+\varepsilon^{m(\eta-y)}\right)=\mathrm{P}$, in differentiating $\mathrm{P}.\cos\overline{nt-\mathrm{M}}$ we may omit $\frac{d^2\mathrm{P}}{dx^2}$. Thus we have

$$\frac{d}{dx}(\mathrm{P}.\cos\overline{nt-\mathrm{M}})=\frac{d\mathrm{P}}{dx}.\cos\overline{nt-\mathrm{M}}+\mathrm{P}.m.\sin\overline{nt-\mathrm{M}}$$

$$-\frac{d^2}{dx^2}(\mathrm{P}.\cos\overline{nt-\mathrm{M}})=-\left(2\frac{d\mathrm{P}}{dx}m+\mathrm{P}\frac{dm}{dx}\right)\sin\overline{nt-\mathrm{M}}+m^2\mathrm{P}.\cos\overline{nt-\mathrm{M}}.$$

Add to this the first term $=-m^2\mathrm{P}.\cos\overline{nt-\mathrm{M}}$

and the expression for F becomes $-\left(2\frac{d\mathrm{P}}{dx}m+\mathrm{P}\frac{dm}{dx}\right)\sin\overline{nt-\mathrm{M}}$

$$=-2m^{\frac{1}{2}}.\frac{d}{dx}(\mathrm{P}m^{\frac{1}{2}}).\sin\overline{nt-\mathrm{M}}$$

$$=-2n^2.m^{\frac{1}{2}}.\frac{d}{dx}\{\mathrm{A}.m^{-\frac{5}{2}}(\varepsilon^{m(y-\eta)}+\varepsilon^{m(\eta-y)})\}.\sin\overline{nt-\mathrm{M}}.$$

Expanding the differential coefficient, we should have one term multiplied by A and another by $\frac{d\mathrm{A}}{dx}$; and by proper determination of $\frac{1}{\mathrm{A}}.\frac{d\mathrm{A}}{dx}$ we should be able to make the expression for $\mathrm{F}=0$ for any one value of y; but it is not possible to make it $=0$ for all values of y; and thus it appears that some force, though perhaps extremely small, is necessary to maintain the sort of undulation which we have supposed.

Whole force, from the bottom to the surface, assumed to be 0.

(242.) Among the different conditions on which we may fix for the determination of $\frac{d\mathrm{A}}{dx}$, the following appears the most reasonable; that upon the whole, from the bottom to the surface of the water, the horizontal force necessary to maintain the assumed wave-motion shall be 0, or that $\int_y\mathrm{F}$ shall $=0$. We cannot here perform the integration under the differential sign, because the limits of the integration will be η and k, the former of which is a function of x. Expanding the differential therefore, we find F=

$$\left\{\begin{array}{l}-2n^2\frac{d\mathrm{A}}{dx}.\frac{1}{m}.(\varepsilon^{m(y-\eta)}+\varepsilon^{m(\eta-y)})-2n^2\mathrm{A}\frac{1}{m}.\frac{dm}{dx}(y-\eta)(\varepsilon^{m(y-\eta)}-\varepsilon^{m(\eta-y)})\\+3n^2\mathrm{A}.\frac{1}{m^2}.\frac{dm}{dx}(\varepsilon^{m(y-\eta)}+\varepsilon^{m(\eta-y)})+2n^2\mathrm{A}\frac{d\eta}{dx}(\varepsilon^{m(y-\eta)}-\varepsilon^{m(\eta-y)})\end{array}\right\}\sin\overline{nt-\mathrm{M}}.$$

For $\int_y\mathrm{F}$, the general integral is

$$\left\{\begin{array}{l}-2n^2\frac{d\mathrm{A}}{dx}.\frac{1}{m^2}.(\varepsilon^{m(y-\eta)}-\varepsilon^{m(\eta-y)})-2n^2\mathrm{A}\frac{1}{m^2}.\frac{dm}{dx}(y-\eta)(\varepsilon^{m(y-\eta)}+\varepsilon^{m(\eta-y)})\\+5n^2\mathrm{A}.\frac{1}{m^3}.\frac{dm}{dx}.(\varepsilon^{m(y-\eta)}-\varepsilon^{m(\eta-y)})+2n^2\mathrm{A}\frac{1}{m}.\frac{d\eta}{dx}(\varepsilon^{m(y-\eta)}+\varepsilon^{m(\eta-y)})\end{array}\right\}\sin\overline{nt-\mathrm{M}},$$

which from $y=\eta$ to $y=k$ is

$$\left\{\begin{array}{l}-2n^2\frac{d\mathrm{A}}{dx}.\frac{1}{m^2}.(\varepsilon^{m(k-\eta)}-\varepsilon^{m(\eta-k)})-2n^2\mathrm{A}.\frac{1}{m^2}.\frac{dm}{dx}(k-\eta)(\varepsilon^{m(k-\eta)}+\varepsilon^{m(\eta-k)})\\+5n^2\mathrm{A}.\frac{1}{m^3}.\frac{dm}{dx}(\varepsilon^{m(k-\eta)}-\varepsilon^{m(\eta-k)})+2n^2\mathrm{A}.\frac{1}{m}.\frac{d\eta}{dx}(\varepsilon^{m(k-\eta)}+\varepsilon^{m(\eta-k)})-4n^2\mathrm{A}.\frac{1}{m}.\frac{d\eta}{dx}\end{array}\right\}\sin\overline{nt-\mathrm{M}}$$

$$=-2n^2m^{\frac{1}{2}}\left\{\frac{d\mathrm{A}}{dx}.m^{-\frac{5}{2}}.(\varepsilon^{m(k-\eta)}-\varepsilon^{m(\eta-k)})+\mathrm{A}\frac{d}{dx}\{m^{-\frac{5}{2}}.(\varepsilon^{m(k-\eta)}-\varepsilon^{m(\eta-k)})\}+2\mathrm{A}.m^{-\frac{3}{2}}.\frac{d\eta}{dx}\right\}\sin\overline{nt-\mathrm{M}}.$$

Making this $=0$, we find

$$\frac{1}{\mathrm{A}}.\frac{d\mathrm{A}}{dx}=\frac{-\frac{d}{dx}\{m^{-\frac{5}{2}}.(\varepsilon^{m(k-\eta)}-\varepsilon^{m(\eta-k)})\}-2m^{-\frac{3}{2}}.\frac{d\eta}{dx}}{m^{-\frac{5}{2}}(\varepsilon^{m(k-\eta)}-\varepsilon^{m(\eta-k)})}$$

whence

$$\mathrm{A}=\frac{\mathrm{C}m^{\frac{5}{2}}}{\varepsilon^{m(k-\eta)}-\varepsilon^{m(\eta-k)}}\times\varepsilon^{\mathrm{Q}},$$

where

$$\frac{d\mathrm{Q}}{dx}=\frac{-2m\frac{d\eta}{dx}}{\varepsilon^{m(k-\eta)}-\varepsilon^{m(\eta-k)}}.$$

Coefficient of horizontal motion.

(243.) The coefficient of horizontal displacement of particles at the surface is

$$\mathrm{A}(\varepsilon^{m(k-\eta)}+\varepsilon^{m(\eta-k)})=\mathrm{C}.m^{\frac{5}{2}}.\frac{\varepsilon^{m(k-\eta)}+\varepsilon^{m(\eta-k)}}{\varepsilon^{m(k-\eta)}-\varepsilon^{m(\eta-k)}}.\varepsilon^{\mathrm{Q}}=\mathrm{C}.m^{\frac{5}{2}}.\frac{mg}{n^2}.\varepsilon^{\mathrm{Q}}=\frac{\mathrm{C}g}{n^2}m^{\frac{7}{2}}.\varepsilon^{\mathrm{Q}}.$$

(244.) The expression for the vertical displacement of particles at the surface, or K, consists of a large term and a small one, which may be represented by $B.\sin\overline{nt-M}+b.\cos\overline{nt-M}$. Making $\frac{b}{B}=\tan\alpha$, this expression $=\sqrt{B^2+b^2}.\sin\overline{nt-M+\alpha}$; but as b is small, $\sqrt{B^2+b^2}$ will not differ sensibly from B. The coefficient therefore of vertical displacement $=B$

Coefficient of vertical motion.

$$=A\,(\varepsilon^{m(k-\eta)}-\varepsilon^{m(\eta-k)})=C.m^{\frac{5}{2}}.\varepsilon^{Q}.$$

(245.) In order then fully to understand the changes in the magnitude of the waves, we have now only to estimate the exponential ε^{Q}. It does not appear that the requisite integration for the exponent can be effected, unless a value be assigned for η in terms of x. But the following limiting values will give a good idea of its general value.

Value of coefficient for short waves.

(246.) 1st. When the waves are short in proportion to the depth (as in common waves, or in the ordinary swell of the sea), m or $\frac{2\pi}{\lambda}$ is large; therefore $\varepsilon^{m(k-\eta)}$ is very large, and $\dfrac{m\frac{d\eta}{dx}}{\varepsilon^{m(k-\eta)}-\varepsilon^{m(\eta-k)}}$ is insignificantly small: therefore its integral $=0$; and the exponential term $=\varepsilon^{0}=1$. Thus we have this theorem. When the water is deep in proportion to the length of the waves, the coefficient of horizontal displacement varies as $m^{\frac{3}{2}}$ or inversely as $\lambda^{\frac{3}{2}}$; and the coefficient of vertical displacement varies as $m^{\frac{5}{2}}$ or inversely as $\lambda^{\frac{5}{2}}$. This theorem is not much in error if the depth be even as small as half the length of a wave.

Value of coefficient for long waves.

(247.) 2nd. When the waves are long in proportion to the depth (as in the tide-wave), m is small, and $\varepsilon^{m(k-\eta)}-\varepsilon^{m(\eta-k)}=2m\,(k-\eta)$ nearly; therefore the exponent $=-2\int\dfrac{m\frac{d\eta}{dx}}{2m(k-\eta)}=-\int\dfrac{\frac{d\eta}{dx}}{k-\eta}=\log\,(k-\eta)$; and the exponential term $=\varepsilon^{\log(k-\eta)}=k-\eta$. But when m is small, the equation $m=\frac{n^2}{g}.\dfrac{\varepsilon^{m(k-\eta)}+\varepsilon^{m(\eta-k)}}{\varepsilon^{m(k-\eta)}-\varepsilon^{m(\eta-k)}}$ becomes $m=\frac{n^2}{g}.\frac{2}{2m(k-\eta)}$; therefore $m=\frac{n}{\sqrt{g}}.\frac{1}{(k-\eta)^{\frac{1}{2}}}$; $m^{\frac{3}{2}}=\frac{n^{\frac{3}{2}}}{g^{\frac{3}{4}}}.\frac{1}{(k-\eta)^{\frac{3}{4}}}$; $m^{\frac{5}{2}}=\frac{n^{\frac{5}{2}}}{g^{\frac{5}{4}}}.\frac{1}{(k-\eta)^{\frac{5}{4}}}$. Substituting these in the expressions for A and B we have this theorem. When the water is shallow in proportion to the length of the waves, the coefficient of horizontal displacement varies as $\overline{\text{the depth}}|^{-\frac{3}{4}}$ or as $m^{\frac{3}{2}}$, or inversely as $\lambda^{\frac{3}{2}}$; and the coefficient of vertical displacement varies as $\overline{\text{the depth}}|^{-\frac{1}{4}}$, or as $m^{\frac{1}{2}}$, or inversely as $\lambda^{\frac{1}{2}}$.

(248.) It may be worth while to examine into the value of F at the surface. We have already found for F the expression $-2n^2m^{\frac{1}{2}}.\frac{d}{dx}\{Am^{-\frac{3}{2}}(\varepsilon^{m(y-\eta)}+\varepsilon^{m(\eta-y)})\}.\sin\overline{nt-M}$; and putting k for y, the value of F at the surface is $-2n^2m^{\frac{1}{2}}.\frac{d}{dx}\{Am^{-\frac{3}{2}}(\varepsilon^{m(k-\eta)}+\varepsilon^{m(\eta-k)})\}.\sin\overline{nt-M}$; which, on substituting for $A(\varepsilon^{m(k-\eta)}+\varepsilon^{m(\eta-k)})$ the value already found, becomes

$$-2Cgm^{\frac{1}{2}}\frac{d}{dx}\{m^2.\varepsilon^{Q}\}\sin\overline{nt-M}.$$

$$=4Cgm^{\frac{3}{2}}.\varepsilon^{Q}\times\left\{\frac{m^2\frac{d\eta}{dx}}{\varepsilon^{m(k-\eta)}-\varepsilon^{m(\eta-k)}}-\frac{dm}{dx}\right\}.\sin\overline{nt-M}.$$

The sign of the coefficient of $\sin\overline{nt-M}$ will depend entirely on the sign of the quantity within the large brackets; the external multiplier being essentially positive when C is positive; that is, when A is positive. Now suppose the wave to be moderately long, or m to be moderately small. On differentiating the equation

$$\log n^2=\log mg+\log\,(\varepsilon^{m(k-\eta)}-\varepsilon^{m(\eta-k)})-\log\,(\varepsilon^{m(k-\eta)}+\varepsilon^{m(\eta-k)})$$

and then expanding the exponentials to the third power of $m(k-\eta)$, we find

$$\frac{dm}{dx}=\frac{m\frac{d\eta}{dx}}{2(k-\eta)+\frac{2}{3}m^2(k-\eta)^3}.$$

Force necessary at the surface, to maintain the motion.

Expanding the exponentials in the term $\dfrac{m^2\dfrac{d\eta}{dx}}{\varepsilon^{m(k-\eta)}-\varepsilon^{m(\eta-k)}}$ in the same manner, we find for the quantity within the large brackets

$$\frac{m\dfrac{d\eta}{dx}}{2(k-\eta)+\dfrac{1}{3}m^2(k-\eta)^3}-\frac{m\dfrac{d\eta}{dx}}{2(k-\eta)+\dfrac{2}{3}m^2(k-\eta)^3};$$

which, supposing the canal to become more shallow as the wave advances, that is, supposing $\dfrac{d\eta}{dx}$ to be positive, is evidently a very small positive quantity. The expression for F at the surface may therefore be represented by $+\text{E}.\sin\overline{nt-\text{M}}$. Now the elevation of the water, or K, has for its principal term $-\text{A}(\varepsilon^{m(k-\eta)}-\varepsilon^{m(\eta-k)})\sin\overline{nt-\text{M}}$; consequently at the crest of a wave, or where K is greatest and positive, $\sin\overline{nt-\text{M}}=-1$; therefore at the crest of the wave, $\text{F}=-\text{E}$. That is, the force, which must act at the crest of the wave to maintain the particles in the state of wave-motion, must be in the direction opposite to that in which the wave is advancing; or, supposing no such force to act, the particles at the crest of the wave will spring forwards from the wave, or will *break* towards the shallow side. This seems to be a complete explanation of the breaking of waves over the edge of a sunk shoal.

Breaking of waves over sunk shoals, &c. explained.

Cause of the surf.

(249.) The breaking of the surf upon a beach is not, perhaps, entirely to be ascribed to the cause which we have assigned for breakers over sunk banks; although that cause undoubtedly produces a great part of the effect. The excessive extent of disturbance of the particles of the water is probably one of the principal causes. As $k-\eta$ is diminished, m is increased or λ diminished; that is, on the water becoming shallower, the waves become shorter. And as we have seen, the elevation of the high parts and the depression of the low parts become greater, so that the general character of the waves is becoming steeper. Moreover, as the height of the wave bears a large proportion to the depth of the water, the front of the wave becomes, from that cause, very steep (203.). At the crest of the wave (nearly) $\sin\overline{nt-\text{M}}$ as we have found $=-1$, or $nt-\text{M}=\dfrac{3\pi}{2}$; therefore at the crest of the wave, X, which depends on $\cos\overline{nt-\text{M}}$, is 0; in front of the crest, M is greater, $nt-\text{M}$ is less than $\dfrac{3\pi}{2}$, and X therefore is negative, or the particles are thrown backwards towards the crest, and therefore (in addition to the cause already assigned) on account of the rapidly increasing coefficient of X as the breadth diminishes, the steepness of the front of the wave rapidly increases. At the same time, the particles on the crest are themselves moving in the direction of the wave-motion, and with a velocity which becomes greater and greater (for the particles which happen to be on the crest) as the wave approaches the shore. It is evident that the limit to these circumstances is, that the front of the wave becomes as steep as a wall, while the uppermost particles are moving towards the shore and the lowermost from the shore; that the former, therefore, will tumble over the latter; and this is the motion of surf.

Investigation when the breadth is not uniform.

(250.) Hitherto we have supposed the breadth of the canal uniform; or, rather, we have taken no account whatever of its breadth. We will now suppose the breadth of a narrow canal to be variable.

Problem.—To investigate the circumstances of the change of wave-motion in a narrow canal of uniform depth whose breadth at different points is different.

(251.) Let β, the breadth of the canal, be considered a function of x. It is easily seen that the equation of continuity must now be altered. For in figure 8, the small parallelogram ps is carried forward to the position PS, where the breadth of the canal is different; namely, is $\beta+\dfrac{d\beta}{dx}\text{X}$ instead of β: and, therefore, instead of making $hl=h\times\left(1+\dfrac{d\text{X}}{dx}\right)\times l\times\left(1+\dfrac{d\text{Y}}{dy}\right)$, as in (145.), we must make

$$\beta\times hl=\beta\left(1+\frac{1}{\beta}\cdot\frac{d\beta}{dx}\text{X}\right)\times h\left(1+\frac{d\text{X}}{dx}\right)\times l\left(1+\frac{d\text{Y}}{dy}\right):$$

from which we find

$$0=\frac{1}{\beta}\cdot\frac{d\beta}{dx}\text{X}+\frac{d\text{X}}{dx}+\frac{d\text{Y}}{dy};$$

and, integrating with respect to y,

$$\text{Y}=-\int_y\left(\frac{d\text{X}}{dx}+\frac{\text{X}}{\beta}\cdot\frac{d\beta}{dx}\right)\text{ (from 0 to } y\text{)}.$$

The equation of equal pressure remains as before; namely,

$$\frac{d^2X}{dt^2}=F+\frac{d}{dx}\left\{-gK-\int_y \frac{d^2Y}{dt^2}\,(y \text{ to } k)\right\}.$$

(252.) We shall now proceed as in the case of variable depth, assuming that the expression for the wave-displacement may be represented by the same formula as if the breadth were uniform, with proper alteration of the constants. The assumption, however, is much simpler than where the depth is variable, inasmuch as we have no reason for assuming the expression for the phase to be different (the velocity of the wave, as depending on the depth, being everywhere the same). Thus, then, we have for X, $A(\varepsilon^{my}+\varepsilon^{-my})\cos\overline{nt-mx}$, where A is a function of x, and m is constant, connected with n by the equation $n^2=gm.\dfrac{\varepsilon^{mk}-\varepsilon^{-mk}}{\varepsilon^{mk}+\varepsilon^{-mk}}$.

(253.) The expression $\dfrac{dX}{dx}+\dfrac{X}{\beta}.\dfrac{d\beta}{dx}$ becomes

$$(\varepsilon^{my}+\varepsilon^{-my})\left\{\frac{dA}{dx}.\cos\overline{nt-mx}+mA.\sin\overline{nt-mx}+\frac{A}{\beta}.\frac{d\beta}{dx}.\cos\overline{nt-mx}\right\};$$

from which we obtain for Y,

$$-(\varepsilon^{my}-\varepsilon^{-my})\left\{\frac{1}{m}.\frac{dA}{dx}.\cos\overline{nt-mx}+A.\sin\overline{nt-mx}+\frac{1}{m}.\frac{A}{\beta}.\frac{d\beta}{dx}.\cos\overline{nt-mx}\right\};$$

therefore $$\frac{d^2Y}{dt^2}=(\varepsilon^{my}-\varepsilon^{-my})\left\{\frac{n^2}{m}.\frac{dA}{dx}.\cos\overline{nt-mx}+n^2A.\sin\overline{nt-mx}+\frac{n^2}{m}.\frac{A}{\beta}.\frac{d\beta}{dx}.\cos\overline{nt-mx}\right\},$$

and $$-\int_y\frac{d^2Y}{dt^2}\,(y \text{ to } k)=(\varepsilon^{my}+\varepsilon^{-my}-\varepsilon^{mk}-\varepsilon^{-mk})\left\{\frac{n^2}{m^2}.\frac{dA}{dx}.\cos\overline{nt-mx}+\frac{n^2}{m}A.\sin\overline{nt-mx}+\frac{n^2}{m^2}.\frac{A}{\beta}.\frac{d\beta}{dx}.\cos\overline{nt-mx}\right\}.$$

Also $$-gK=(\varepsilon^{mk}-\varepsilon^{-mk})\left\{\frac{g}{m}.\frac{dA}{dx}.\cos\overline{nt-mx}+gA.\sin\overline{nt-mx}+\frac{g}{m}.\frac{A}{\beta}.\frac{d\beta}{dx}.\cos\overline{nt-mx}\right\}.$$

Therefore, by virtue of the equation $n^2(\varepsilon^{mk}+\varepsilon^{-mk})=gm(\varepsilon^{mk}-\varepsilon^{-mk})$,

$$-gK-\int_y\frac{d^2Y}{dt^2}\,(y \text{ to } k)=(\varepsilon^{my}+\varepsilon^{-my})\left\{\frac{n^2}{m^2}.\frac{dA}{dx}.\cos\overline{nt-mx}+\frac{n^2}{m}A.\sin\overline{nt-mx}+\frac{n^2}{m^2}.\frac{A}{\beta}.\frac{d\beta}{dx}.\cos\overline{nt-mx}\right\}.$$

(254.) In differentiating this quantity with regard to x, we shall suppose the breadth to vary slowly, and shall, therefore, as in the similar differentiation of the last Problem, reject all products of differential coefficients, and all differential coefficients of the second order. Thus we obtain

$$\frac{d}{dx}\left\{-gK-\int_y\frac{d^2Y}{dt^2}\,(y \text{ to } k)\right\}=$$

$$(\varepsilon^{my}+\varepsilon^{-my})\left\{\frac{2n^2}{m}.\frac{dA}{dx}.\sin\overline{nt-mx}n^2-A.\cos\overline{nt-mx}+\frac{n^2}{m}.\frac{A}{\beta}.\frac{d\beta}{dx}.\sin\overline{nt-mx}\right\}.$$

Also $$\frac{d^2X}{dt^2}=(\varepsilon^{my}+\varepsilon^{-my})\,(-n^2A.\cos\overline{nt-mx}).$$

Subtracting the former from the latter,

$$F=-(\varepsilon^{my}+\varepsilon^{-my})\left\{\frac{2n^2}{m}.\frac{dA}{dx}+\frac{n^2}{m}.\frac{A}{\beta}.\frac{d\beta}{dx}\right\}\sin\overline{nt-mx}.$$

Coefficients of horizontal and vertical motion.

This expression vanishes, or no force is necessary to maintain the wave-motion, if $2\dfrac{dA}{dx}+\dfrac{A}{\beta}.\dfrac{d\beta}{dx}=0$, or if $\dfrac{2}{A}.\dfrac{dA}{dx}+\dfrac{1}{\beta}.\dfrac{d\beta}{dx}=0$, or if $\log(A^2\beta)=\log C^2$, or $A=\dfrac{C}{\sqrt{\beta}}$. That is, the coefficient of horizontal motion will be inversely as the square root of the breadth of the canal. The coefficient of vertical motion (in the same manner as in (244.)), will not sensibly differ from $-A(\varepsilon^{my}-\varepsilon^{-my})$, or, at the surface, $-A(\varepsilon^{mk}-\varepsilon^{-mk})$: and thus the height of the waves will be inversely as the square root of the breadth of the canal.

(255.) We might, without difficulty, have combined the investigations of the two last Problems; and we should have found the expression for the variation of the coefficient of either motion in a canal where both breadth and depth vary, to be represented by the product of those found separately in the two Problems.

(256.) Before quitting these important investigations, we shall make one remark. When waves travel along a canal of uniform breadth and depth, the motion of every particle, as we have seen (182.) and (183.), is in a circle, or an ellipse whose major axis is horizontal: if in a circle, its motion in that circle is uniform; if in an ellipse, the horizontal motion is, at any instant of time, in the same proportion to the whole horizontal motion as in a circle, and the vertical motion is also in the same proportion to the whole vertical motion as in a circle.

And (184.) the greatest horizontal motion forwards occurs when a particle is at the top of a wave: the greatest horizontal motion backwards occurs when a particle is at the bottom of a wave; and the horizontal motion is 0 when a particle is at its mean elevation. These assertions are not true if the depth or breadth is variable. Thus, in the case of variable depth; the horizontal displacement at the surface $=X=A(\varepsilon^{m(k-\eta)}+\varepsilon^{m(\eta-k)})\cos\overline{nt-M}$: the horizontal motion $=-nA(\varepsilon^{m(k-\eta)}+\varepsilon^{m(\eta-k)})\sin\overline{nt-M}$: this is greatest when $nt-M=\frac{3\pi}{2}$, $\sin\overline{nt-M}=-1$, $\cos\overline{nt-M}=0$; substituting these values in the expression for K, it becomes $A(\varepsilon^{m(k-\eta)}-\varepsilon^{m(\eta-k)})$, which is not the greatest value of K; for the expression for K is of the form $B\sin\overline{nt-M}+b\cos\overline{nt-M}$, the greatest value of which is $\sqrt{B^2+b^2}$, where $B=A(\varepsilon^{m(k-\eta)}-\varepsilon^{m(\eta-k)})$. The horizontal motion is 0 when $\sin\overline{nt-M}=0$; which (if we take the case of still water following the high water, implying that t has been increased above the value which made $\sin\overline{nt-M}=-1$) gives $nt-M=0$, $\cos nt-M=1$; and the corresponding value of K is

$$-\frac{dA}{dx}\cdot\frac{1}{m}(\varepsilon^{m(k-\eta)}-\varepsilon^{m(\eta-k)})-A\frac{1}{m}\cdot\frac{dm}{dx}(k-\eta)(\varepsilon^{m(k-\eta)}+\varepsilon^{m(\eta-k)})+A\frac{1}{m^2}\cdot\frac{dm}{dx}(\varepsilon^{m(k-\eta)}-\varepsilon^{m(\eta-k)})+A\frac{d\eta}{dx}(\varepsilon^{m(k-\eta)}+\varepsilon^{m(\eta-k)})$$

$$=-\frac{d}{dx}\left\{\frac{A}{m}(\varepsilon^{m(k-\eta)}-\varepsilon^{m(\eta-k)})\right\}$$

$$=-\frac{d}{dx}\cdot\frac{\text{coefficient of vertical displacement}}{m}.$$

In the case of short waves in deep water, we have found the coefficient of vertical displacement to vary as $m^{\frac{3}{2}}$; therefore this value of K varies as $-\frac{d}{dx}m^{\frac{1}{2}}$: as the depth diminishes, m increases, and this value of K is negative. But in the case of long waves in shallow water (as the tide-wave), the coefficient of vertical displacement varies as $m^{\frac{1}{2}}$; therefore this value of K varies as $-\frac{d}{dx}\cdot\frac{1}{m^{\frac{1}{2}}}$: as the depth diminishes, m increases, and K is therefore positive. That is, in the case of long waves in shallow water, where the depth diminishes, the water is sensibly elevated above its mean height when the flow ceases; and in like manner it is sensibly depressed below its mean height when the ebb ceases.

Cessation of flow occurs earlier than if the depth and breadth were uniform.

(257.) In the case of variable width; the horizontal displacement at the surface $=A(\varepsilon^{mk}+\varepsilon^{-mk})\cos\overline{nt-mx}$; the horizontal motion $=-nA(\varepsilon^{mk}+\varepsilon^{-mk})\sin\overline{nt-mx}$: this is 0, for the still water following the high water, when $\sin\overline{nt-mx}=0$, $\cos\overline{nt-mx}=1$; the corresponding value of K is

$$-(\varepsilon^{mk}-\varepsilon^{-mk})\left\{\frac{1}{m}\cdot\frac{dA}{dx}+\frac{1}{m}\cdot\frac{A}{\beta}\cdot\frac{d\beta}{dx}\right\}=-\frac{1}{m\beta}(\varepsilon^{mk}-\varepsilon^{-mk})\frac{d}{dx}(A\beta).$$

But we have found $A=\frac{C}{\beta^{\frac{1}{2}}}$, therefore $A\beta=C\beta^{\frac{1}{2}}$; and therefore $K=-\frac{1}{m\beta}(\varepsilon^{mk}-\varepsilon^{-mk})\frac{d}{dx}(C\beta^{\frac{1}{2}})$ If the breadth diminishes as x increases, the differential coefficient $\frac{d}{dx}(C\beta^{\frac{1}{2}})$ is negative, and therefore the value of K is positive. That is, where the breadth diminishes, the water is sensibly elevated above its mean height when the flow ceases; and in like manner, the water is sensibly depressed below its mean height when the ebb ceases.

(258.) When (as usually happens) both these causes unite, that is when the channel along which the tide-wave is propagated becomes at the same time shallower and narrower, it may happen that the height of the water above its mean level is considerable when the flow ceases.

Investigation for a canal whose section is of any form and varies in any degree, when the wave is very long.

(259.) The change in the circumstances of the wave produced by the variation of the section of the channel in form as well as in breadth and in depth, when the wave is supposed to be very long, may be found more simply in the following manner.

(260.) Let the equation to the section, as in (218.), be $z=\phi(y,x)$, x being introduced into the function because the form and dimensions vary with x; and $u=\int_y z=\psi(y,x)$. For the same reason as in (238.), suppose X to be represented by $A\cos\overline{nt-M}$, where $M=\int_x m$. Now we have found in (220.) that the function expressing a single wave on a uniform canal whose section is defined by the equation $u=\psi(y,x)$, is $X=\chi(v't-x)=\chi\left(t\sqrt{\frac{g\psi(k)}{\phi(k)}}-x\right)=\chi_{,}\left(nt-nx\sqrt{\frac{\phi(k)}{g\psi(k)}}\right)$. Comparing this with our usual form for X in a uniform canal, namely, $A\cos\overline{nt-mx}$, it appears that $m=n\sqrt{\dfrac{\phi(k)}{g\psi(k)}}$, and therefore in the variable canal

$$M=n\int_x\sqrt{\frac{\phi(k,x)}{g\psi(k,x)}}.$$

(261.) Now the fluid, which when at rest was included between two vertical planes whose co-ordinates were x and $x+h$, is now included between two vertical planes whose co-ordinates are $x+X$ and $x+X+h+\dfrac{dX}{dx}h$ nearly; and the area of the vertical section, which was $\psi(k,x)$, is now $\psi(V,x+X)$, or $\psi(k+\overline{V-k},x+X)$, or $\left(\text{observing that } \dfrac{d\,.\,\psi(k,x)}{dk}=\phi(k,x)\right)$ $\psi(k,x)+\phi(k,x).\overline{V-k}+\dfrac{d\,.\,\psi(k,x)}{dx}X$. Thus the equation of continuity becomes

$$h\times\psi(k,x)=h\left(1+\frac{dX}{dx}\right)\times\left\{\psi(k,x)+\phi(k,x).\overline{V-k}+\frac{d.\psi(k,x)}{dx}X\right\},$$

or

$$0=\frac{dX}{dx}.\psi(k,x)+\phi(k,x).\overline{V-k}+\frac{d.\psi(k,x)}{dx}X;$$

whence

$$V-k=-\frac{1}{\phi(k,x)}\frac{d}{dx}\Big(X.\psi(k,x)\Big).$$

(262.) The equation of pressure will be as before, $\dfrac{d^2X}{dt^2}=-g\dfrac{dV}{dx}.\dfrac{1}{1+\dfrac{dX}{dx}}=-g\dfrac{dV}{dx}$ nearly. Substituting for V, this becomes

$$\frac{d^2X}{dt^2}=g\frac{d}{dx}\left\{\frac{1}{\phi(k,x)}\frac{d}{dx}\Big(X.\psi(k,x)\Big)\right\}.$$

Performing the interior differentiation on the assumption $X=A\cos\overline{nt-M}$, where A is a function of x, and $\dfrac{dM}{dx}=n\sqrt{\dfrac{\phi(k,x)}{g\psi(k,x)}}$, this becomes

$$\frac{d^2X}{dt^2},\text{ or }-n^2A.\cos\overline{nt-M}=g\frac{d}{dx}\left\{\frac{1}{\phi(k,x)}\frac{d}{dx}\Big(A.\psi(k,x)\Big)\cos\overline{nt-M}+nA\sqrt{\frac{\psi(k,x)}{g\phi(k,x)}}\sin\overline{nt-M}\right\}.$$

Performing the second differentiation, with the limitation that, as $\phi(k,x)$ and $\psi(k,x)$ vary very slowly, their second differentials and squares of first differentials may be rejected,

$$-n^2A.\cos\overline{nt-M}=n\sqrt{g}.\left\{\frac{1}{\sqrt{\phi(k,x).\psi(k,x)}}\frac{d}{dx}\Big(A.\psi(k,x)\Big)+\frac{d}{dx}\left\{\frac{A.\psi(k,x)}{\sqrt{\phi(k,x).\psi(k,x)}}\right\}\right\}\text{sih}\,\overline{nt-M}$$
$$-n^2A.\cos\overline{nt-M}.$$

Let $A\psi(k,x)=\nu$, $\sqrt{\phi(k,x).\psi(k,x)}=\mu$: then this equation reduces itself to

$$\frac{1}{\mu}.\frac{d\nu}{dx}+\frac{d}{dx}\left\{\frac{\nu}{\mu}\right\}=0,$$

or

$$\frac{2}{\mu}.\frac{d\nu}{dx}-\frac{\nu}{\mu^2}.\frac{d\mu}{dx}=0,$$

or

$$\frac{2}{\nu}.\frac{d\nu}{dx}-\frac{1}{\mu}.\frac{d\mu}{dx}=0,$$

the integral of which is $\dfrac{\nu^2}{\mu}=C^2$, or $A^2.\{\psi(k,x)\}^{\frac{3}{2}}.\{\phi(k,x)\}^{-\frac{1}{2}}=C^2$,

or

$$A=C.\{\psi(k,x)\}^{-\frac{3}{4}}.\{\phi(k,x)\}^{\frac{1}{4}}.$$

This is the coefficient of horizontal displacement of the particles.

Coefficient of horizontal motion.

(263.) For the vertical displacement,

$$K=V-k=-\frac{1}{\phi(k,x)}\frac{d}{dx}\Big(X.\psi(k,x)\Big)=-\frac{1}{\phi(k,x)}.\frac{d}{dx}\Big(A.\psi(k,x).\cos\overline{nt-M}\Big)$$
$$=-\frac{1}{\phi(k,x)}\left\{\frac{d}{dx}\Big(A.\psi(k,x)\Big).\cos\overline{nt-M}+A.\psi(k,x).\sin\overline{nt-M}\,.\,n\sqrt{\frac{\phi(k,x)}{g\psi(k,x)}}\right\},$$

in which the first term may be neglected as much smaller than the second. Thus

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$$\mathrm{K}=-\frac{n}{\sqrt{g}}.\mathrm{A}\sqrt{\frac{\psi\,(k,x)}{\phi\,(k,x)}}.\ \sin\overline{nt-\mathrm{M}}.$$

Coefficient of vertical motion.

Putting for A its value found above, we have for the coefficient of vertical displacement

$$-\frac{n}{\sqrt{g}}\mathrm{C}\,.\{\psi\,(k,x)\}^{-\frac{1}{4}}\,.\,\{\phi\,(k,x)\}^{-\frac{1}{4}}.$$

(264.) For instance: if the section of the canal be everywhere a rectangle, $\phi\,(k,x)=$ breadth, and $\psi\,(k,x)=$ breadth × depth: which gives for the coefficient of vertical displacement

$$-\frac{n}{\sqrt{g}}\mathrm{C}.\{\text{breadth}\}^{-\frac{1}{2}}.\{\text{depth}\}^{-\frac{1}{4}},$$

a result which agrees with those found for long waves in shallow water in (247.) and (254.).

(265.) The two following problems regarding the motion of variable waves on a sea of uniform depth are interesting, as applying to some most important phænomena.

Elevations increase from wave to wave.

Problem.—The amplitude of each successive wave in a long series is the same, but the elevations of the waves increase progressively from wave to wave, the same elevation always corresponding to the same place: to find the forces which must act on the particles of water to maintain this state of undulation.

(266.) Here the value of Y at the surface, or K, must have a factor of $\sin\overline{nt-mx}$, which itself depends upon x. We may therefore suppose X to have such a factor: in other respects the form assumed for X may be the same as in the case of uniform waves. Let therefore

$$\mathrm{X}=(\varepsilon^{my}+\varepsilon^{-my})\,.\,\phi\,(x).\ \cos\overline{nt-mx}:$$

where n and m are connected by the equation $n^2=mg\dfrac{\varepsilon^{mk}-\varepsilon^{-mk}}{\varepsilon^{mk}+\varepsilon^{-mk}}$. Then

$$\frac{d\mathrm{Y}}{dy}=-\frac{d\mathrm{X}}{dx}=-(\varepsilon^{my}+\varepsilon^{-my})\,\frac{d}{dx}\Big(\phi\,(x)\cos\overline{nt-mx}\Big);$$

integrating from 0 to y,

$$\mathrm{Y}=\frac{1}{m}\,(-\varepsilon^{my}+\varepsilon^{-my})\,\frac{d}{dx}\Big(\phi\,(x).\ \cos\overline{nt-mx}\Big);$$

$$\mathrm{K}=\frac{1}{m}\,(-\varepsilon^{mk}+\varepsilon^{-mk})\,\frac{d}{dx}\Big(\phi\,(x).\cos\overline{nt-mx}\Big):$$

$$\frac{d^2\mathrm{Y}}{dt^2}=\frac{n^2}{m}(\varepsilon^{my}-\varepsilon^{-my})\,\frac{d}{dx}\Big(\phi\,(x).\cos\overline{nt-mx}\Big)$$

$$\int_y\frac{d^2\mathrm{Y}}{dt^2}\,(y\text{ to }k)=\frac{n^2}{m^2}\,(\varepsilon^{mk}+\varepsilon^{-mk}-\varepsilon^{my}-\varepsilon^{-my})\,\frac{d}{dx}\Big(\phi\,(x).\ \cos\overline{nt-mx}\Big):$$

therefore $$g\mathrm{K}+\int_y\frac{d^2\mathrm{Y}}{dt^2}(y\text{ to }k)=-\frac{n^2}{m^2}\,(\varepsilon^{my}+\varepsilon^{-my})\,\frac{d}{dx}\Big(\phi\,(x).\ \cos\overline{nt-mx}\Big):$$

the terms $\dfrac{g}{m}\,(-\varepsilon^{mk}+\varepsilon^{-mk})+\dfrac{n^2}{m^2}\,(\varepsilon^{mk}+\varepsilon^{-mk})$ destroying one another by virtue of the equation between n and m.

Also $$\frac{d^2\mathrm{X}}{dt^2}=-n^2\,(\varepsilon^{my}+\varepsilon^{-my}).\phi\,(x)\cos\overline{nt-mx}.$$

Hence F or $\dfrac{d^2\mathrm{X}}{dt^2}+\dfrac{d}{dx}\Big\{g\mathrm{K}+\displaystyle\int_y\dfrac{d^2\mathrm{Y}}{dt^2}\,(y\text{ to }k)\Big\}$ becomes

$$-n^2(\varepsilon^{my}+\varepsilon^{-my}).\Big\{\phi\,(x).\ \cos\overline{nt-mx}+\frac{1}{m^2}.\frac{d^2}{dx^2}\Big(\phi\,(x).\ \cos\overline{nt-mx}\Big)\Big\}.$$

Performing the differentiation, this becomes

$$-n^2\,(\varepsilon^{my}+\varepsilon^{-my}).\Big\{\frac{2}{m}.\ \phi'\,(x)\ .\ \sin\overline{nt-mx}+\frac{1}{m^2}.\phi''\,(x)\ .\ \cos\overline{nt-mx}\Big\}.$$

Force necessary to maintain this motion.

If $\phi\,(x)=\mathrm{C}x+\mathrm{D}$, this expression for F becomes $-\dfrac{2\mathrm{C}n^2}{m}\,(\varepsilon^{my}+\varepsilon^{-my}).\ \sin\overline{nt-mx}$. Now when the force is small, or the coefficient C small, the expression for Y will not sensibly differ from $-(\varepsilon^{my}-\varepsilon^{-my}).(\mathrm{C}x+\mathrm{D}).\sin\overline{nt-mx}$. The term ε^{-my} is very small in comparison with ε^{my}, except very near the bottom. The result therefore is this: the force which, acting horizontally upon the particles of water, will maintain such a series of waves as we have supposed, must, for each particle, be nearly proportional to the elevation of that particle above its mean place: the proportion varying slowly, however, from one particle to another. Or we may state it thus: the force must be proportional to the horizontal velocity of each particle, and in the same direction as its motion.

(267.) Now we have nearly such a force in the action of the wind upon the waves. For the part of the wave which is principally or solely exposed to the action of the wind is its upper part. Thus the highest parts alone, or those near the crest of the wave, are urged forward: the lowest parts, or those in the hollow of the wave, either are not urged forward, or (more probably) by the eddies of the wind are actually urged backwards. Moreover, the action of the wind does not sensibly extend to a great depth below the surface: and in this respect it may be considered as fairly represented by ε^{my}. Thus then we have a mathematical explanation of the circumstance that the action of the wind will maintain the motion of a series of waves, whose elevation beginning at the windward shore is 0, and goes on increasing successively from wave to wave, without remarkable alteration from time to time (when they have once attained a certain magnitude). And as the proportion of the force of the wind, in regard to depth, is in pretty good agreement with that required by the theory for continuous unbroken waves, the theory explains the circumstance that, when the waves have attained this certain magnitude, their heads will scarcely be broken by the action of the wind.

The force of the wind corresponds closely with this expression.

(268.) It may, however, be remarked that, in the open sea, the waves of large amplitude only are so much increased as to attract much attention. The reason appears to be that, when the action of the wind has in some degree increased all, the long waves protect the short ones from the continuance of its action upon them. And thus the long waves are conspicuous upon an open sea, not because the short waves are changed into long ones, but because the long ones only are conspicuously increased from the windward shore to the open sea.

In the open sea, the long waves only become important.

(269.) Problem.—The amplitudes of all the waves are equal, and the elevations are all equal at the same time, but increase constantly from time to time: to find the forces which must act on the particles of water to maintain this state of undulation.

The waves increase from time to time.

(270.) Here we shall assume

$$X = (\varepsilon^{my} + \varepsilon^{-my}) \cdot \psi(t) \cdot \cos \overline{nt - mx}.$$

Then

$$\frac{dY}{dy} = -\frac{dX}{dx} = -m\,(\varepsilon^{my} + \varepsilon^{-my}) \cdot \psi(t) \cdot \sin \overline{nt - mx}:$$

integrating from 0 to y,

$$Y = (-\varepsilon^{my} + \varepsilon^{-my}) \cdot \psi(t) \cdot \sin \overline{nt - mx}:$$

$$\frac{d^2Y}{dt^2} = (-\varepsilon^{my} + \varepsilon^{-my}) \frac{d^2}{dt^2}\left(\psi(t) \cdot \sin \overline{nt - mx}\right):$$

$$\int_y \frac{d^2Y}{dt^2}(y \text{ to } k) = \frac{1}{m}\,(-\varepsilon^{mk} - \varepsilon^{-mk} + \varepsilon^{my} + \varepsilon^{-my}) \frac{d^2}{dt^2}\left(\psi(t) \cdot \sin \overline{nt - mx}\right):$$

$$K = (-\varepsilon^{mk} + \varepsilon^{-mk}) \cdot \psi(t) \cdot \sin \overline{nt - mx}:$$

therefore

$$\frac{d}{dx}\left\{gK + \int_y \frac{d^2Y}{dt^2}(y \text{ to } k)\right\} =$$

$$\frac{d}{dx}\left\{g\,(-\varepsilon^{mk} + \varepsilon^{-mk}) \cdot \psi(t) \cdot \sin \overline{nt - mx} + \frac{1}{m}\,(-\varepsilon^{mk} - \varepsilon^{-mk} + \varepsilon^{my} + \varepsilon^{-my}) \frac{d^2}{dt^2}\left(\psi(t) \cdot \sin \overline{nt - mx}\right)\right\}$$

$$= gm\,(\varepsilon^{mk} - \varepsilon^{-mk}) \cdot \psi(t) \cdot \cos \overline{nt - mx} + (\varepsilon^{mk} + \varepsilon^{-mk} - \varepsilon^{my} - \varepsilon^{-my}) \cdot \frac{d^2}{dt^2}\left(\psi(t) \cdot \cos \overline{nt - mx}\right).$$

Also

$$\frac{d^2X}{dt^2} = (\varepsilon^{my} + \varepsilon^{-my}) \frac{d^2}{dt^2}\left(\psi(t) \cdot \cos \overline{nt - mx}\right).$$

Hence the expression for F or $\frac{d^2X}{dt^2} + \frac{d}{dx} \left. gK + \int_y \frac{d^2Y}{dt^2}(y \text{ to } k)\right\}$ becomes

$$gm\,(\varepsilon^{mk} - \varepsilon^{-mk}) \cdot \psi(t) \cdot \cos \overline{nt - mx} + (\varepsilon^{mk} + \varepsilon^{-mk}) \frac{d^2}{dt^2}\left(\psi(t) \cdot \cos \overline{nt - mx}\right).$$

Performing the differentiation, and observing that $gm\,(\varepsilon^{mk} - \varepsilon^{-mk}) - n^2\,(\varepsilon^{mk} + \varepsilon^{-mk}) = 0$, we have

$$F = (\varepsilon^{mk} + \varepsilon^{-mk})\,\{\psi''(t) \cdot \cos \overline{nt - mx} - 2n \cdot \psi'(\ ) \cdot \sin \overline{nt - mx}\}.$$

Force necessary to maintain this motion.

If $\psi(t) = Ct + D$, we must have

$$F = -2nC\,(\varepsilon^{mk} + \varepsilon^{-mk}) \cdot \sin \overline{nt - mx}.$$

That is: the elevations of the waves will be increased uniformly, provided a horizontal force acts upon every particle, which is equal for all the particles in the same vertical column, and which urges forward those particles that are above their mean places and urges backward those that are below their mean places, according to the law of the sine of the phase.

(271.) Now the action of the wind produces a force strongly resembling this, but not so nearly as before. For the force (as in the former case) does act to urge forward those parts which are above their mean place, and in some degree to urge backwards those which are below their mean place. But it is not nearly equal for the particles at different elevations in the same vertical column: being effective only near the top and insensible for other parts. Hence it appears that there is too much horizontal force at the top of the waves for continuous undulation: and this excess of force is in the direction in which the wave is going, and therefore tends to

The force of the wind nearly represents this force, but not exactly.

push the top of the wave too rapidly. To this cause, as we conceive, is to be ascribed the breaking of the crests of the waves, which always takes place when the wind is raising the sea.

We may proceed in the same manner if $\mathrm{X}=(\varepsilon^{my}+\varepsilon^{-my})\,(\mathrm{A}+\mathrm{B}x+\mathrm{C}t)\cos\overline{ni-mx}$.

Manner in which the wind acts to raise the waves. Limitation to the height of the waves raised by a wind of given force on a sea of given extent.

(272.) The effect of continued action of wind upon the sea may be conceived to show itself in the following manner. It is to be understood that, either from preceding disturbances, or from the trifling irregularities in the action of the wind while the water is smooth, there are very shallow undulations upon the water. When the wind begins to act, it will at first only increase the height of the waves in every part (271.), and during this time the heads of the waves will be broken. But after a time the waves, beginning with the windward shore, will be (for a short distance at least) so much increased, that the power of the wind will merely maintain them in that state without any increase (267.), but for all the sea in advance the wind will still be raising the waves. But as the waves successively attain that height which corresponds, according to the result of (266.), with the height which the wind can just maintain, those waves will no longer be increased, but the waves in advance will still be increased. Thus a wind of given intensity, however long it blows, can only raise the waves at a given point to a certain height: which height, however, will depend upon the distance of that point from the windward shore.

Motion of water under the action of forces similar to the tidal forces.

(273.) We shall now consider the motion of water in a canal of uniform breadth and depth under the action of a given force. The difficulties connected with a general solution of this problem would, in the present state of mathematics, be found insuperable; we shall therefore confine ourselves to a law of force which applies perfectly to the problem of tides.

(274.) Problem.—The water in a canal of uniform breadth and depth is acted on by a horizontal force represented at every point by $\mathrm{H}.\sin\overline{it-mx}$ and by a vertical force represented by $\mathrm{G}.\cos\overline{it-mx}$: to find the nature of the wave which will be produced.

(275.) The equations to be used are those of (224.), supposing the depth uniform or $\eta=0$. They become

$$\mathrm{Y}=-\int_y\frac{d\mathrm{X}}{dx}\,(0\text{ to }y)$$

$$\frac{d^2\mathrm{X}}{dt^2}=\mathrm{H}.\sin\overline{it-mx}+\frac{d}{dx}\left\{-(g+\mathrm{G}.\cos\overline{it-mx})\,(k-y+\mathrm{K})-\int_y\frac{d^2\mathrm{Y}}{dt^2}\,(y\text{ to }k)\right\}.$$

The forces are supposed to be small, and the term $\frac{d}{dx}\,(g.\overline{k-y})$ is evidently $=0$. These considerations reduce the second equation to this form:

$$\frac{d^2\mathrm{X}}{dt^2}=\mathrm{H}.\sin\overline{it-mx}+\frac{d}{dx}\left\{-g\mathrm{K}-\overline{k-y}.\mathrm{G}.\cos\overline{it-mx}-\int_y\frac{d^2\mathrm{Y}}{dt^2}\,(y\text{ to }k)\right\}.$$

Now the least trial would show that the expression for X must depend on $\sin\overline{it-mx}$. Assume therefore

$$\mathrm{X}=\phi''(y).\sin\overline{it-mx};$$

$\phi''(y)$ being a function of y whose form is yet to be determined, and which is conceived as the second derived function from some function $\phi(y)$. Then

$$\frac{d\mathrm{X}}{dx}=-m\phi''(y)\cos\overline{it-mx};\qquad-\int_y\frac{d\mathrm{X}}{dx}=m\phi'(y)\cos\overline{it-mx};$$

from which

$$\mathrm{Y}=m\Big(\phi'(y)-\phi'(0)\Big)\cos\overline{it-mx}.$$

Therefore

$$\frac{d^2\mathrm{Y}}{dt^2}=-i^2m\Big(\phi'(y)-\phi'(0)\Big)\cos\overline{it-mx};$$

$$-\int_y\frac{d^2\mathrm{Y}}{dt^2}\,(y\text{ to }k)=+i^2m\Big(\phi(k)-\phi(y)-\phi'(0).\overline{k-y}\Big)\cos\overline{it-mx};$$

$$-g\mathrm{K}=-gm\Big(\phi'(k)-\phi'(0)\Big)\cos\overline{it-mx}.$$

Adding to these terms $-\overline{k-y}.\mathrm{G}.\cos\overline{it-mx}$, differentiating with regard to x, and putting for $\frac{d^2\mathrm{X}}{dt^2}$ its value $-i^2.\phi''(y).\sin\overline{it-mx}$, our second equation becomes

$$\begin{aligned}-i^2.\phi''(y).\sin\overline{it-mx}=\mathrm{H}.\sin\overline{it-mx}&\\-gm^2.\Big(\phi'(k)-\phi'(0)\Big).\sin\overline{it-mx}&\\-m(k-y).\mathrm{G}.\sin\overline{it-mx}&\\+i^2m^2\Big(\phi(k)-\phi(y)-\phi'(0).\overline{k-y}\Big)\sin\overline{it-mx}.&\end{aligned}$$

(276.) Equating to 0 the terms depending on y, we have

$$-i^2.\phi''(y)=-i^2m^2\phi(y);\ 0=-m(k-y)\,\mathrm{G}-i^2m^2\phi'(0).\overline{k-y}.$$

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The first gives $\phi(y)=A.\varepsilon^{my}+B.\varepsilon^{-my}$. From this we obtain $\phi'(y)=mA.\varepsilon^{my}-mB.\varepsilon^{-my}$; $\phi''(y)=m^2A.\varepsilon^{my}+m^2B.\varepsilon^{-my}$. The second equation gives $G+i^2m\phi'(0)=0$, or $G+i^2m^2A-i^2m^2B=0$, or $B-A=\frac{G}{i^2m^2}$; whence $B=A+\frac{G}{i^2m^2}$; $\phi(y)=A(\varepsilon^{my}+\varepsilon^{-my})+\frac{G}{i^2m^2}\varepsilon^{-my}$; $\phi'(y)=mA(\varepsilon^{my}-\varepsilon^{-my})-\frac{G}{i^2m}\varepsilon^{-my}$. Substituting in those parts of the equation which have not been already destroyed,

$$0=H-gm^2\left(mA(\varepsilon^{mk}-\varepsilon^{-mk})-\frac{G}{i^2m}\varepsilon^{-mk}+\frac{G}{i^2m}\right)+i^2m^2\left(A(\varepsilon^{mk}+\varepsilon^{-mk})+\frac{G}{i^2m^2}\varepsilon^{-mk}\right)$$

or

$$A\{-gm^3(\varepsilon^{mk}-\varepsilon^{-mk})+i^2m^2(\varepsilon^{mk}+\varepsilon^{-mk})\}=-H-G\left\{\frac{gm}{i^2}\varepsilon^{-mk}-\frac{gm}{i^2}+\varepsilon^{-mk}\right\}$$

whence

$$A=\frac{-H+\frac{gm}{i^2}G-\left(1+\frac{gm}{i^2}\right)G\varepsilon^{-mk}}{i^2m^2(\varepsilon^{mk}+\varepsilon^{-mk})-gm^3(\varepsilon^{mk}-\varepsilon^{-mk})}$$

$$B=A+\frac{G}{i^2m^2}=\frac{-H+\frac{gm}{i^2}G+\left(1-\frac{gm}{i^2}\right)G\varepsilon^{mk}}{i^2m^2(\varepsilon^{mk}+\varepsilon^{-mk})-gm^3(\varepsilon^{mk}-\varepsilon^{-mk})}$$

$$\phi''(y)=\frac{-H+\frac{gm}{i^2}G-\left(\frac{gm}{i^2}+1\right)G.\varepsilon^{-mk}}{i^2(\varepsilon^{mk}+\varepsilon^{-mk})-gm(\varepsilon^{mk}-\varepsilon^{-mk})}\varepsilon^{my}+\frac{-H+\frac{gm}{i^2}G-\left(\frac{gm}{i^2}-1\right)G\varepsilon^{mk}}{i^2(\varepsilon^{mk}+\varepsilon^{-mk})-gm(\varepsilon^{mk}-\varepsilon^{-mk})}\varepsilon^{-my}$$

$$m\phi'(y)=\frac{-H+\frac{gm}{i^2}G-\left(\frac{gm}{i^2}+1\right)G.\varepsilon^{-mk}}{i^2(\varepsilon^{mk}+\varepsilon^{-mk})-gm(\varepsilon^{mk}-\varepsilon^{-mk})}\varepsilon^{my}-\frac{-H+\frac{gm}{i^2}G-\left(\frac{gm}{i^2}-1\right)G\varepsilon^{mk}}{i^2(\varepsilon^{mk}+\varepsilon^{-mk})-gm(\varepsilon^{mk}-\varepsilon^{-mk})}\varepsilon^{-my}.$$

(277.) With these expressions forming the values of X and Y at the surface, we obtain the following:

Horizontal and vertical motions of the particles at the surface.

$$\text{X at the surface}=\frac{-H(\varepsilon^{mk}+\varepsilon^{-mk})+G.\frac{gm}{i^2}(\varepsilon^{mk}-2+\varepsilon^{-mk})}{i^2(\varepsilon^{mk}+\varepsilon^{-mk})-gm(\varepsilon^{mk}-\varepsilon^{-mk})}\sin\overline{it-mx}$$

$$\text{Y at the surface, or K}=\frac{-H(\varepsilon^{mk}-\varepsilon^{-mk})+G(\varepsilon^{mk}-2+\varepsilon^{-mk})}{i^2(\varepsilon^{mk}+\varepsilon^{-mk})-gm(\varepsilon^{mk}-\varepsilon^{-mk})}\cos\overline{it-mx}.$$

Upon these expressions we may make the following remarks:

Distinction between *forced* wave and *free* wave.

(278.) 1st. The wave whose motions are defined by the values of $X=\phi''(y).\sin\overline{it-mx}$ and $Y=m\left(\phi'(y)-\phi'(0)\right)\cos\overline{it-mx}$, the particular values of which at the surface we have just exhibited, is that to which we have alluded (173.) by the name of the *forced* tide-wave. Its existence depends entirely on the continuance of the action of the external forces; if those forces ceased to act, the wave depending on $\sin\overline{it-mx}$ would immediately cease to exist. Other waves however would exist, as a consequence of these forces having been previously in action; and some (as we shall presently see) will at all times exist conjointly with the *forced* tide-wave. Thus, (as we shall see,) if the canal be interrupted, there will always exist a wave depending on $\sin\overline{it\pm m'x}$, where i and m' are connected by the equation $i^2=gm'\frac{\varepsilon^{m'k}-\varepsilon^{-m'k}}{\varepsilon^{m'k}+\varepsilon^{-m'k}}$; the magnitude and other circumstances of this wave will depend on the boundaries of the canal. This is what we have called the *free* tide-wave; its period is the same as that of the *forced* tide-wave, but its length is different; the continuance of the forces is not necessary for its existence. There may exist a wave depending on $\sin\overline{nt\pm mx}$, where n and m are connected by the equation $n^2=gm\frac{\varepsilon^{mk}-\varepsilon^{-mk}}{\varepsilon^{mk}+\varepsilon^{-mk}}$, and this would also be a *free* wave; its length is the same as that of the *forced* tide-wave, but its period is different, and for this reason we shall *not* call it a *free tide-wave;* it would not exist as a consequence of interruption of the canal, but as a consequence of sudden commencement or change or cessation of the forces, and its coefficient would depend on these circumstances (as we shall see hereafter).

(279.) 2nd. The expressions may be put into the following form:

$$\text{X at the surface}=\frac{-H+G.\frac{gm}{i^2}.\frac{\varepsilon^{mk}-2+\varepsilon^{-mk}}{\varepsilon^{mk}+\varepsilon^{-mk}}}{i^2-gm.\frac{\varepsilon^{mk}-\varepsilon^{-mk}}{\varepsilon^{mk}+\varepsilon^{-mk}}}\sin\overline{it-mx}$$

$$=\frac{-H+G.\frac{n^2}{i^2}.\frac{\varepsilon^{mk}-2+\varepsilon^{-mk}}{\varepsilon^{mk}-\varepsilon^{-mk}}}{i^2-n^2}\sin\overline{it-mx},$$

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which, since $\varepsilon^{mk}-2+\varepsilon^{-mk}=\left(\varepsilon^{\frac{mk}{2}}-\varepsilon^{-\frac{mk}{2}}\right)^2$, and $\varepsilon^{mk}-\varepsilon^{-mk}=\left(\varepsilon^{\frac{mk}{2}}+\varepsilon^{-\frac{mk}{2}}\right).\left(\varepsilon^{\frac{mk}{2}}-\varepsilon^{-\frac{mk}{2}}\right)$, becomes

$$\text{X at the surface} = \frac{-\text{H}+\text{G}\frac{n^2}{i^2}.\frac{\varepsilon^{\frac{mk}{2}}-\varepsilon^{-\frac{mk}{2}}}{\varepsilon^{\frac{mk}{2}}+\varepsilon^{-\frac{mk}{2}}}}{i^2-n^2}\sin\overline{it-mx}.$$

Similarly

$$\text{K} = \frac{-\text{H}.\frac{n^2}{gm}+\text{G}.\frac{n^2}{gm}.\frac{\varepsilon^{mk}-2+\varepsilon^{-mk}}{\varepsilon^{mk}-\varepsilon^{-mk}}}{i^2-n^2}\cos\overline{it-mx}$$

$$= \frac{-\text{H}.\frac{n^2}{gm}+\text{G}\frac{n^2}{gm}.\frac{\varepsilon^{\frac{mk}{2}}-\varepsilon^{-\frac{mk}{2}}}{\varepsilon^{\frac{mk}{2}}+\varepsilon^{-\frac{mk}{2}}}}{i^2-n^2}\cos\overline{it-mx}.$$

Now mk is a small quantity. For, putting λ for the length of the forced tide-wave, (which at the equator $=12500$ miles), $m=\frac{2\pi}{\lambda}$, and $mk=2\pi\frac{k}{\lambda}$, so that, even if the depth of the sea were 25 miles, mk would be $=\frac{2\pi}{500}=\frac{6\cdot 28}{500}$. Therefore $\varepsilon^{\frac{mk}{2}}-\varepsilon^{-\frac{mk}{2}}=mk$ very nearly, and $\varepsilon^{\frac{mk}{2}}+\varepsilon^{-\frac{mk}{2}}=2$ very nearly, and therefore the expressions become

$$\text{X at the surface} = \frac{-\text{H}+\text{G}\frac{n^2}{i^2}.\frac{mk}{2}}{i^2-n^2}\sin\overline{it-mx};$$

$$\text{K} = \frac{-\text{H}\frac{n^2}{gm}+\text{G}\frac{n^2}{gm}.\frac{mk}{2}}{i^2-n^2}\cos\overline{it-mx}.$$

Effect of the vertical force is insignificant.

Consequently, if we consider G and H to be quantities not very dissimilar in magnitude, (which we shall find to be true,) the term depending on G in each of these expressions is wholly insignificant in comparison with that depending on H; and thus we arrive at this remarkable conclusion, that *the effect of the vertical disturbing force upon the phænomena of the tides is insignificant*, the whole of the sensible effect being due to the horizontal force. In (28.) and (69.) we have found the same result from different ways of treating the tides. There is no exception to this theorem as applied to the expression for K; if i were very small, it might not hold strictly with regard to the expression for X; but that is of small importance.

If the period of the forced wave were equal to the period of a free wave, the motion would be infinite.

(280.) 3rd. If the period of the *forced* tide-wave were the same as that of a *free* wave of the second class, that is, if i were equal to n, m being the same in the two waves, the denominator in the expressions for X and K would vanish, or X and K would become infinite. In this case then the expressions fail. It would seem that, if we suppose a canal surrounding the earth to be acted on by the forces of the sun and moon following the law assumed in this Problem, and if i were equal to n, the only interpretation that can be put on this failure would be,—that the motion of the water cannot be oscillatory in the manner of a wave, but that it must be that of a torrent of unequal depth passing round the earth so as to follow the apparent motion of the sun or moon. We shall find, however, that the introduction of friction prevents the expression from ever becoming infinite.

If the period of the forced wave is smaller, there is low water under the Moon.

(281.) 4th. If the period of the forced tide-wave be less than that of a free wave of the second class, (that is, if the wave be urged along more rapidly than it would go alone, or if the water be shallow,) or if i be greater than n, (i and n being, by (166.) inversely as the periods,) the denominator is positive; and the expression for K (omitting the term depending on G) is of the form $-\text{C}\cos\overline{it-mx}$. Now conceive the Moon to go round the Earth (apparently) from east to west; x must be measured in the same direction; because then, by proper determination of the value of m, the parts of the Earth which happen to be under the Moon will always have the same certain value of $\overline{it-mx}$. Conceive the horizontal force created by the Moon's action to be 0 for the parts under the Moon; to be positive at the parts, to a certain extent, which she has passed, and to be negative at the parts, to a certain extent, on the side to which she is approaching. (This is supposing, in other words, that to a certain extent the horizontal force caused by the Moon's action urges the water towards that part of the Earth which is under the Moon; a supposition which correctly represents the actual case.) Then $\overline{it-mx}$ must be 0 for the parts under the Moon. (For then, in the parts which the Moon has left, x is less than under the Moon, $\overline{it-mx}$ is positive, and therefore the force, which we have assumed to be H $\sin\overline{it-mx}$, is positive there; in the parts to which the Moon is approaching, x is greater than under the Moon, $\overline{it-mx}$ is negative, and therefore the force or H $\sin\overline{it-mx}$ is negative there.) Consequently the elevation of the water under the Moon is $-\text{C}.\cos 0=-\text{C}$. That is, it is low water immediately under the Moon. The same conclusion will be found in (16.) and (109.).

(282.) 5th. In like manner, if the period of the forced tide-wave were greater than that of the free wave of the second class, (that is, if the water were so immensely deep that the wave would travel alone more rapidly than the disturbing forces urge it along,) or if i were less than n, the denominator would be negative, and there would be high water under the Moon.

If the period is very long, the form of the water is that of equilibrium nearly.

(283.) 6th. If the complete change of forces occupy a long time, that is if i be small, $K = +\frac{H}{gm}\cos\overline{it-mx}$ nearly. This is the same expression that would have been found from a theory of equilibrium, or by (152.); so that in this case the water assumes very nearly the form of equilibrium.

(284.) For shallow water, it will be remarked that $n^2 = gkm^2$ nearly, and the whole of the expressions may be altered by that substitution. And, as in (166.) and (165.), we may put $\frac{2\pi}{\tau'}$ for i, and $\frac{2\pi}{\lambda}$ for m: then τ' is the period of the changes of the *force*, which is the same as the period of the *forced wave*, and λ is the length of the wave. The expression for K, omitting the term depending on G, will thus be changed to

$$\frac{-H.km}{i^2-gkm^2}\cos\overline{it-mx}, \text{ or } -\frac{Hk}{2\pi}.\frac{\lambda.\tau'^2}{\lambda^2-gk.\tau'^2}\cos\overline{it-mx}:$$

and, if the depth be *very* small,

$$K = -\frac{Hk}{2\pi}.\frac{\tau'^2}{\lambda}.\cos\overline{it-mx}$$

In showing that in this case the elevation of the tide is proportional to the depth of the sea, we have obtained the same result as that deduced from Laplace's Theory of Tides, in (98.), (101.), and (107.).

(285.) The preceding conclusions are very important, as showing that the amount of elevation of the water under the action of forces depends in a most remarkable degree upon other circumstances than the magnitude of the forces. One is, the depth of the sea: another is, the periodic time of the forces. As depending upon the former, it appears that, if there were two parallel canals of different depths acted on by precisely the same forces, there might be high water in one when there was low water in the adjacent part of the other: or there might be elevations and depressions at the same time in both, but their magnitudes might have any proportion whatever. As depending upon the latter, it appears that, if there were two forces acting simultaneously upon the water in the same canal, the periods of those forces being different, (as, for instance, the forces depending upon the action of the Sun and the Moon,) the high water produced by one force might bear the same relation to the phases of that force which the low water produced by the other bears to the phases of that other force: (thus low water of the solar tide might accompany the transit of the Sun, and high water of the lunar tide might accompany the transit of the Moon, in the same canal.) Or the phases of the two tides might stand in the same relation to the phases of the two forces, but the proportion of their magnitudes to the magnitudes of the forces might differ in any degree whatever.

Coefficient of force supposed variable.

(286.) The conclusions of (93.), as to the effect of a variable coefficient of the force, apply here: but as we are able to give expressions here which could not be given in those investigations, we shall repeat a small part of the process. If the force, instead of being $H.\sin\overline{it-mx}$, were $(H+H'\cos i't).\sin\overline{it-mx}$ or $H.\sin\overline{it-mx} + \frac{H'}{2}\sin\overline{(i+i')t-mx} + \frac{H'}{2}\sin\overline{(i-i')t-mx}$, the expression for K would be (supposing the water shallow),

$$\frac{-Hkm}{i^2-gkm^2}\cos\overline{it-mx} - \frac{1}{2}.\frac{H'km}{(i+i')^2-gkm^2}\cos\overline{(i+i')t-mx} - \frac{1}{2}.\frac{H'km}{(i-i')^2-gkm^2}\cos\overline{(i-i')t-mx};$$

and if i' were very small, that is, if the change of the variable coefficient were slow, we might expand to the first power of i', and it would become

$$\frac{-Hkm}{i^2-gkm^2}\cos\overline{it-mx} - \frac{1}{2}\,\frac{H'km}{i^2-gkm^2}\left\{\cos\overline{(i+i')t-mx} + \cos\overline{(i-i')t-mx}\right\}$$

$$+\frac{1}{2}.\frac{H'km.2ii'}{(i^2-gkm^2)^2}\left\{\cos\overline{(i+i')t-mx} - \cos\overline{(i-i')t-mx}\right\}$$

$$= -\frac{km}{i^2-gkm^2}(H+H'\cos i't).\cos\overline{it-mx} - \frac{2kmii'}{(i^2-gkm^2)^2}H'.\sin i't.\sin(it-mx).$$

(287.) The time of low water on a given day (supposing the variation of $i't$ in the day to be insensible) will be found by making

$$\tan(it-mx) = \frac{2ii'}{i^2-gkm^2}.\frac{H'\sin i't}{H+H'\cos i't};$$

and, therefore, when $\sin i't$ is positive, it will be later than that determined by making $it-mx=0$, as in (281.).

(288.) The greatest amount of elevation or depression on that day, as in (93.), will be

$$\frac{km}{i^2-gkm^2}\sqrt{\left\{(H+H'\cos i't)^2 + \frac{4i^2i'^2}{(i^2-gkm^2)^2}H'^2\sin^2 i't\right\}}.$$

If H′ be much smaller than H, this expression $=\frac{km}{i^2-gkm^2}(\text{H}+\text{H}'\cos i't)$ nearly.

(289.) If the term H do not exist, the whole force being $=\text{H}'\cos i't.\sin\overline{it-mx}$, the expression for greatest elevation or depression on any day =

$$\frac{\text{H}'km}{i^2-gkm^2}\sqrt{\left\{\cos^2 i't+\frac{4i^2i'^2}{(i^2-gkm^2)^2}\sin^2 i't\right\}}.$$

This quantity never vanishes, even on the days on which $\cos i't$ vanishes: but it is, on those days, either maximum or minimum. It is maximum if $2ii'$ be greater than i^2-gkm^2, and minimum if $2ii'$ be less than i^2-gkm^2. In the former case, however, it will be necessary to use for the coefficients of $\cos i't.\cos\overline{it-mx}$ and $\sin i't.\sin\overline{it-mx}$ their accurate values

$$\frac{-\text{H}'km}{2}\left(\frac{1}{(i+i')^2-gkm^2}+\frac{1}{(i-i')^2-gkm^2}\right)\text{ and }\frac{-\text{H}'km}{2}\left(\frac{1}{(i-i')^2-gkm^2}-\frac{1}{(i+i')^2-gkm^2}\right).$$

Subsection 5.—On the Method of using the free Tide-Waves and forced Tide-Waves, and of introducing the limits of Canals in general.

(290.) Before we exhibit the method of introducing the *free tide-wave* and other *free* waves, which we have mentioned as coexisting with the *forced tide-wave*, we will shortly remark on the general solution of the partial differential equation of waves. The same remarks apply to all other linear partial differential equations.

Solution which represents the forced tide-wave may be made more general by adding any number of expressions for free tide-waves.

(291.) We have found a solution X for the equation $\frac{d^2\text{X}}{dt^2}=\text{F}+\frac{d}{dx}\left\{-g\text{K}+\int_y\frac{d^2\text{Y}}{dt^2}\right\}$: where F is a given function of x and t. Now suppose that we know that each of the quantities X_1, X_2, X_3, &c. will satisfy the equation $\frac{d^2\text{X}'}{dt^2}=0+\frac{d}{dx}\left\{-g\text{K}'+\int_y\frac{d^2\text{Y}'}{dt^2}\right\}$: the peculiarity of which, as distinguished from the former, is, that it contains no term independent of X′ $\left(\text{K}'\right.$ being a particular value of Y′, and Y′ being formed from X′ by integrating $\left.-\int_y\frac{d\text{X}'}{dx}\right)$. Then the sum of all the quantities $\text{X}+\text{X}_1+\text{X}_2+$&c. will satisfy the equation $\frac{d^2\text{X}}{dt^2}=\text{F}+\frac{d}{dx}\left\{-g\text{K}+\int_y\frac{d^2\text{Y}}{dt^2}\right\}$. For, upon substituting $\text{X}+\text{X}_1+\text{X}_2+$&c., in this last equation, instead of X, we have

$$\frac{d^2(\text{X}+\text{X}_1+\text{X}_2+\&\text{c.})}{dt^2}=\text{F}+\frac{d}{dx}\left\{-g(\text{K}+\text{K}_1+\text{K}_2+\&\text{c.})+\int_y\frac{d^2(\text{Y}+\text{Y}_1+\text{Y}_2+\&\text{c.})}{dt^2}\right\};$$

which is necessarily true, because it is the same as the sum of all the equations

$$\frac{d^2\text{X}}{dt^2}=\text{F}+\frac{d}{dx}\left\{-g\text{K}+\int_y\frac{d^2\text{Y}}{dt^2}\right\};\quad\frac{d^2\text{X}_1}{dt^2}=0+\frac{d}{dx}\left\{-g\text{K}_1+\int_y\frac{d^2\text{Y}_1}{dt^2}\right\},\ \&\text{c.}:$$

each of which is separately true. Therefore $\text{X}+\text{X}_1+\text{X}_2+$&c. may be used as a solution of the equation $\frac{d^2\text{X}}{dt^2}=\text{F}+\frac{d}{dx}\left\{-g\text{K}+\int_y\frac{d^2\text{Y}}{dt^2}\right\}$: and it is more general than X merely, and therefore can better be adapted to the circumstances of the case.

(292.) In the problem of (274.), &c., we have found $\text{C}.\cos\overline{it-mx}$* for a solution of the equation $\frac{d^2\text{X}}{dt^2}=\text{F}+\frac{d}{dx}\left\{-g\text{K}+\int_y\frac{d^2\text{Y}}{dt^2}\right\}$. But we know that $\text{A}_1\cos(n_1t-m_1x+a_1)$, $\text{B}_1\cos(n_1t+m_1x+b_1)$, $\text{A}_2\cos(n_2t-m_2x+a_2)$, $\text{B}_2\cos(n_2t+m_2x+b_2)$, &c. are solutions of the equation $\frac{d^2\text{X}'}{dt^2}=\frac{d}{dx}\left\{-g\text{K}'+\int_y\frac{d^2\text{Y}'}{dt^2}\right\}$, provided only that $n_1^2=gm_1\frac{\varepsilon^{m_1k}-\varepsilon^{-m_1k}}{\varepsilon^{m_1k}+\varepsilon^{-m_1k}}$, &c. Therefore we may add any or all of these terms to $\text{C}.\cos\overline{it-mx}$ for the solution of $\frac{d^2\text{X}}{dt^2}=\text{F}+\frac{d}{dx}\left\{-g\text{K}+\int_y\frac{d^2\text{Y}}{dt^2}\right\}$. We shall have occasion only to add terms in which $n_1=i$, or terms in which $m_1=m$. The nature of the conditions to be satisfied will determine our choice. If for some given instant of time a certain condition is to apply to all parts of the canal, the coefficient of x must be the same as in $\text{C}.\cos\overline{it-mx}$; that is, m_1 must $=m$. But if at some certain part of the canal a certain

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* We use indifferently the sine or the cosine, as one is changed into the other by changing the origin of x or t.

condition is to hold during all time, the coefficient of t must be the same as in $C.\cos\overline{it-mx}$, or n_1 must $=i$. The following instances will illustrate this.

(293.) Problem.—The disturbing force of the Moon, represented by the formula $H.\cos\overline{it-mx}$, begins to act suddenly when $t=0$: to find the nature of the waves produced on a canal: the water having been previously at rest.

Force begins to act at a certain instant.

(294.) The value for X must be $C.\cos\overline{it-mx}+X_1+X_2+\&c.$: and the condition that the water was in its position of rest in every part of the fluid, and also was actually at rest, when $t=0$, requires that

$$C.\cos\overline{it-mx}+X_1+X_2+\&c.=0 \text{ when } t=0 \text{ for every value of } x;$$

and that $$\frac{d}{dt}(C.\cos\overline{it-mx}+X_1+X_2+\&c.)=0 \text{ when } t=0 \text{ for every value of } x.$$

The only forms of X_1 and X_2 which can satisfy these conditions are

$$A.\cos(nt-mx+\alpha) \text{ and } B.\cos(nt+mx+\beta),$$

where $n^2=gm\dfrac{\varepsilon^{mk}-\varepsilon^{-mk}}{\varepsilon^{mk}+\varepsilon^{-mk}}$. The conditions now become

$$C\cos mx+A\cos(-mx+\alpha)+B\cos(mx+\beta)=0.$$
$$iC\sin mx-nA\sin(-mx+\alpha)-nB\sin(mx+\beta)=0.$$

Expanding the sines and cosines, we obtain $C+A\cos\alpha+B\cos\beta=0$; $A\sin\alpha-B\sin\beta=0$; $iC+nA\cos\alpha-nB\cos\beta=0$; $-nA\sin\alpha-nB\sin\beta=0$. The second and fourth equations give $A\sin\alpha=0$, $B\sin\beta=0$; the first and third give $A\cos\alpha=-\dfrac{(i+n)C}{2n}$, $B\cos\beta=\dfrac{(i-n)C}{2n}$. Hence $X_1=-\dfrac{(i+n)C}{2n}\cos\overline{nt-mx}$, $X_2=\dfrac{(i-n)C}{2n}\cos\overline{nt+mx}$: and the whole expression for X is

$$C.\cos\overline{it-mx}-\frac{(i+n)C}{2n}\cos\overline{nt-mx}+\frac{(i-n)C}{2n}\cos\overline{nt+mx}.$$

(295.) This instance is one of pure curiosity, given only as an example. The following, probably, is one of real application.

Canal bounded at both ends.

Problem.—A canal, the water of which is acted on by the forces of the moon's attraction, is bounded at both extremities: to find the nature of the waves produced on it.

(296.) The condition here is, that, at each extremity, X shall $=0$, and $\dfrac{dX}{dt}$ shall $=0$, whatever be the value of t. The second equation is evidently included in the first; so that, in fact, we have only one condition for each end of the canal. A moment's consideration will show that, the term for the forced tide-wave being $C.\cos\overline{it-mx}$, the other terms must have the same multiple of t. Let the value of X, therefore, at the surface be assumed $=$

$$C.\cos\overline{it-mx}\ +A.\cos\overline{it-lx+\alpha}\ +B.\cos\overline{it+lx+\beta},$$

where $i^2=gl\dfrac{\varepsilon^{lk}-\varepsilon^{-lk}}{\varepsilon^{lk}+\varepsilon^{-lk}}$. Let the values of x at the two extremities of the canal be a and b. Then, at one end of the canal, $X=C.\cos\overline{it-ma}+A.\cos\overline{it-la+\alpha}+B.\cos\overline{it+la+\beta}$; which is to be $=0$ for all values of t. At the other end, $X=C.\cos\overline{it-mb}+A.\cos\overline{it-lb+\alpha}+B.\cos\overline{it+lb+\beta}$, which also is to be $=0$ for all values of t. Expanding, and separating the coefficients of $\cos it$ and $\sin it$, we have these four equations:

$$C.\cos ma+A.\cos\overline{\alpha-la}+B.\cos\overline{\beta+la}=0;$$
$$C.\sin ma-A.\sin\overline{\alpha-la}-B.\sin\overline{\beta+la}=0;$$
$$C.\cos mb+A.\cos\overline{\alpha-lb}+B.\cos\overline{\beta+lb}=0;$$
$$C.\sin mb-A.\sin\overline{\alpha-lb}-B.\sin\overline{\beta+lb}=0.$$

Without here going through the details of the solution, it is plain that the conditions are satisfied by the following formula:

$$X=C.\cos\overline{it-mx}-\frac{C}{\sin l(b-a)}\{\cos\overline{it-mb}.\sin\overline{lx-la}-\cos\overline{it-ma}.\sin\overline{lx-lb}\};$$

which, upon multiplying the sines and cosines together, according to the rules of Trigonometry, may be put into the form $C.\cos\overline{it-mx}+A.\cos\overline{it-lx+\alpha}+B.\cos\overline{it+lx+\beta}$, and which becomes 0 when $x=a$ or $=b$. The first term of the expression is the *forced* tide-wave; the part within the brackets represents the *free* tide-waves, which may be conceived as the combination of the reflections of the forced tide-wave from the ends of the canal, and whose speed does not depend on the speed of the Moon's change of place.

(297.) It is proper to remark, that the condition $X=0$ cannot be strictly satisfied at all depths. For in the case of the forced tide-wave the value of X at different depths depends on $\varepsilon^{my}+\varepsilon^{-my}$, and in the case of the free tide-wave it depends on $\varepsilon^{ly}+\varepsilon^{-ly}$; and these are not exactly in the same proportion at different depths. It would seem, therefore, that there must, theoretically, be a breaking of water on the coast, in consequence of the oscillation of the tide. But when the wave is of very long period, (as is true of the tide-wave,) both $\varepsilon^{ly}+\varepsilon^{-ly}$ and $\varepsilon^{my}+\varepsilon^{-my}$ are at all depths sensibly $=2$, and, therefore, the condition $X=0$ may be considered as satisfied at all depths.

(298.) The corresponding value of K, or $-\int_y \frac{dX}{dx}(0 \text{ to } k)$, $\left(\text{observing that } \int_y (\varepsilon^{my}+\varepsilon^{-my}) = \frac{1}{m}(\varepsilon^{my}-\varepsilon^{-my}) = \frac{2my}{m}\right.$ nearly $= y \times (\varepsilon^{my}+\varepsilon^{-my})$ nearly, and that the same holds when l is put for m, $\Big)$ is

$$-Cmk.\sin\overline{it-mx}+\frac{Clk}{\sin(lb-la)}\{\cos\overline{it-mb}.\cos\overline{lx-la}-\cos\overline{it-ma}.\cos\overline{lx-lb}\}.$$

In this case the disturbance may become infinite.

It may be interesting to examine the value of this expression in some particular cases.

(299.) 1st. If $\sin\overline{lb-la}=0$, that is, if $\overline{lb-la}=\pi$, or 2π, or 3π, &c., or if the length of the canal is any multiple of half the length of the free tide-wave, this expression becomes infinite. In reality the wave will become so large that the amount of friction, &c. will be so great as to neutralize the moon's force. This will be seen more clearly in the next section.

Tides in a canal of small extent.

(300.) 2d. If $\overline{lb-la}$ be small, that is, if the canal be short, we may proceed by approximation. Suppose a and b to be small quantities: x must also be a small quantity of the same order. Expanding $\sin\overline{it-mx}$, $\sin\overline{lx-la}$, &c., and substituting for the sines and cosines of the small arcs the series in terms of the arc, and preserving only the first power which remains in the resulting expressions, we find the following:

$$X=\cos it.C.\frac{m^2-l^2}{2}.\overline{x-a}.\overline{b-x}$$

$$K=\cos it.Ck(m^2-l^2).\left(x-\frac{a+b}{2}\right).$$

Consist simply of oscillations from one end to the other.

The first of these expressions shows that the horizontal motion will be greatest in the middle of the canal's length, and will diminish gradually both ways to the ends, where it is 0. The second shows that there is no variation of level at the middle of the canal's length, but that the variation of level in other parts is proportional to the distance from the middle, elevation taking place on one side of the middle at the same time as depression on the other side, so that the surface of the fluid remains sensibly plane, though inclined to the horizon. The law of motion as regards the time is the usual oscillatory law expressed by $\cos it$; but the motion of every particle differs in this respect from the motion of particles in an open sea affected by the tide: that here, the greatest horizontal displacement happens at the same time as the greatest vertical displacement; whereas, in an open sea, the greatest horizontal displacement happens when the vertical displacement is 0, and *vice versâ*. (182.) and (184.).

Solution in general case when one term is more important than the others.

(301.) 3d. In the general case, if we take the centre of the canal for the origin of our measures, or make $a=-b$, we have

$$X=C\cos it\left\{\cos mx-\frac{\cos mb}{\cos lb}\cos lx\right\}+C\sin it\left\{\sin mx-\frac{\sin mb}{\sin lb}\sin lx\right\}$$

$$K=Ck\cos it\left\{m.\sin mx-\frac{l.\cos mb}{\cos lb}\sin lx\right\}+Ck\sin it\left\{-m\cos mx+\frac{l\sin mb}{\sin lb}\cos lx\right\}.$$

In general, no simple meaning can be given to these expressions. In the particular case of $\cos lb$ being very small, the principal term of K is $-\cos it.\frac{Ckl\cos mb}{\cos lb}\sin lx$, which shows that, though there may be many oscillating elevations and depressions, yet all the waves will be of a stationary character in regard of space; that all the oscillations take place at the same time; and that an elevation on one side of the middle happens at the same instant as a depression at the same distance on the other side of the middle. If $\sin lb$ is very small, then the principal term in the expression for K is $\sin it.\frac{Ckl\sin mb}{\sin lb}\cos lx$: in this case the waves are stationary in place, and all the oscillations happen at the same time: but the elevations or depressions at equal distances from the middle towards both ends are similar.

(302.) Problem.—A canal, whose waters are acted on by the forces of the Moon, &c., communicates at one end with an open sea, whose waters have a tidal fluctuation, and is closed at the other end: to find the circumstances of tidal motion of the waters in the canal.

Tides in a deep gulf.

(303.) Let the mouth of the canal be the origin of the measures, its length being a; let the elevation of the sea-waters at the mouth of the canal be expressed by $A.\sin\overline{nt+B}$. Then the conditions to which our expressions for X and K must be subject, are these: that when $x=0$, K must $=A.\sin\overline{nt+B}$, and when $x=a$, X must

$=0$ for all values of t. Suppose, then, that the value of X given by the solution of the differential equations is $C.\cos\overline{nt-px}$. The complete value of X, as before (296.), will be

$$C.\cos\overline{nt-px}+D.\cos\overline{nt-mx+E}+F.\cos\overline{nt+mx+G},$$

where $n^2=gm\frac{\varepsilon^{mk}-\varepsilon^{-mk}}{\varepsilon^{mk}+\varepsilon^{-mk}}$. And the complete value of K, as in (298.), will be

$$-Cpk.\sin\overline{nt-px}-Dmk.\sin\overline{nt-mx+E}+Fmk.\sin\overline{nt+mx+G}.$$

Our two conditions, therefore, become the following:

$$-Cpk.\sin nt-Dmk.\sin\overline{nt+E}+Fmk.\sin\overline{nt+G}=A.\sin\overline{nt+B}$$

$$C.\cos\overline{nt-pa}+D.\cos\overline{nt-ma+E}+F.\cos\overline{nt+ma+G}=0.$$

Expanding the sines and cosines, and equating the coefficients of $\sin nt$ and $\cos nt$, we obtain the following equations for the determination of $D\sin E$, $D\cos E$, $F\sin G$, and $F\cos G$:

$$-Cpk-mk.D\cos E+mk.F\cos G=A\cos B$$

$$-mk.D\sin E+mk.F\sin G=A\sin B$$

$$C\cos pa+\cos ma.D\cos E+\sin ma.D\sin E+\cos ma.F\cos G-\sin ma.F\sin G=0$$

$$C\sin pa-\cos ma.D\sin E+\sin ma.D\cos E-\cos ma.F\sin G-\sin ma.F\cos G=0.$$

Solving these equations, and substituting the values so found in the expression for X, we find at length

$$X=\frac{A}{mk\cos ma}\sin\overline{nt+B}.\sin\overline{ma-mx}+C\cos\overline{nt-px}+\frac{Cp}{m\cos ma}\sin nt.\sin\overline{ma-mx}-\frac{C}{\cos ma}\cos\overline{nt-pa}.\cos mx\,;$$

from which

$$K=\frac{A}{\cos ma}\sin\overline{nt+B}.\cos\overline{ma-mx}-Cpk.\sin\overline{nt-px}+\frac{Cpk}{\cos ma}\sin nt.\cos\overline{ma-mx}-\frac{Cmk}{\cos ma}\cos\overline{nt-pa}.\sin mx\,;$$

which, it is easily seen, satisfy our equations of condition. The following considerations suggest themselves from the examination of this expression.

(304.) 1st. In a river or sea, such as we have supposed, the expression for the elevation of the tide is by no means a simple one: it may be represented by the combination of three stationary waves (of the nature of free waves) and one progressive wave (a forced tide-wave), whose compounded effects cannot easily be represented by those of a single wave, even though considered changeable.

(305.) 2nd. If we put the expression for K under the form $P\sin nt-Q\cos nt$, and make $\frac{Q}{P}=\tan\theta$, then $K=\sqrt{P^2+Q^2}.\sin(nt-\theta)$, and the time of high water will be determined by making $nt=\theta+90°$, or $\tan nt=-\cot\theta=-\frac{P}{Q}$; and the whole rise of tide will be $2\sqrt{P^2+Q^2}$. In the case before us,

$$P=\frac{A.\cos B.\cos\overline{ma-mx}}{\cos ma}-Cpk.\cos px+\frac{Cpk.\cos\overline{ma-mx}}{\cos ma}-\frac{Cmk.\sin pa.\sin mx}{\cos ma}$$

$$-Q=\frac{A.\sin B.\cos\overline{ma-mx}}{\cos ma}+Cpk.\sin px-\frac{Cmk.\cos pa.\sin mx}{\cos ma}.$$

The expression, therefore, for nt at high water, as depending on x, will be one of great complexity; and that for $\frac{d\theta}{dx}$, on which the apparent velocity of the tide-wave will depend, will be complicated. It does not appear that in the general case we have any reason to think that the tide-wave will appear to travel always in the same direction.

(306.) 3rd. If the tidal oscillations of the sea be insensible, or $A=0$, the remaining terms still have the same kind of complexity as in the last problem. But if $\cos ma$ be also very small, then the expression may be reduced to a single term multiplying $\sin mx$; and the tidal oscillation will consist of a stationary wave, or a series of stationary waves, in all which the oscillations take place simultaneously, and in which the horizontal motion of the particles and the vertical motion are greatest at the same time, or vanish at the same time.

Tide in a river stopped by a barrier.

(307.) 4th. If the effect of the moon's forces on the waters of the canal is insensible, then $C=0$, and the value of K is reduced to $\frac{A}{\cos ma}.\sin\overline{nt+B}.\cos\overline{ma-mx}$. This shows that all the oscillations in different parts of the canal take place at the same time; or, if ma is less than 90°, that it is high water in every part of the canal at the same time. But the whole rise of the waters $=\frac{2A}{\cos ma}\cos\overline{ma-mx}$ is different in different parts of the canal; and, if ma is less than 90°, it increases from the mouth of the canal to its termination. The corresponding value of X is $\frac{A}{mk\cos ma}.\sin\overline{nt+B}.\sin\overline{ma-mx}$: this shows that the greatest horizontal displacement of the particles occurs at the same time as the greatest vertical displacement; and the whole horizontal motion, or $\frac{2A}{mk\cos ma}\sin\overline{ma-mx}$ diminisnes from the mouth of the canal to its termination.

(308.) As this investigation applies in some degree to the case of various gulfs and rivers, it may be proper to examine how far it is modified by taking into account the extent of the fluctuation.

Problem.—A canal is closed at one end and open at the other end to a tidal sea: to find the nature of the tide-wave in the canal, the elevation of the water being supposed to bear a sensible proportion to the whole depth.

Tide in a river stopped by a barrier, when the motion of the particles is large.

(309.) The equation, as in (196.), will be

$$\frac{d^2X}{dt^2}-v^2\frac{d^2X}{dx^2}=v^2\frac{d^2X}{dx^2}\times\left\{-3\frac{dX}{dx}+6\left(\frac{dX}{dx}\right)^2-\&c.\right\},$$

where $v^2=gk$. An approximate value of X is

$$\frac{A}{mk\cos ma}.\sin\overline{mvt+B}.\sin\overline{ma-mx}.$$

Substituting this value in the second side of the equation, as far as the term $\frac{dX}{dx}$, and proceeding in the solution exactly in the same manner as in (198.) &c., we find the following expression for X:

$$\begin{aligned}X=&\frac{A}{mk\cos ma}.\sin\overline{ma-mx}.\sin\overline{mvt+B}\\&+\frac{A^2}{k^2\cos^2 ma}\left\{-\frac{3}{16m}\sin\overline{2ma-2mx}-\frac{3}{16}x.\cos\overline{2ma-2mx}.\cos\overline{2mvt+2B}\right\}\\&+\phi(vt+x)+\psi(vt-x);\end{aligned}$$

from which we find the elevation of the water, at the place whose distance from the mouth of the canal, measured along the canal-bank, is $=x'$, to be represented by the following expression:

$$\begin{aligned}&\frac{A}{\cos ma}.\cos\overline{ma-mx'}.\sin\overline{mvt+B}\\&+\frac{1}{8}.\frac{A^2}{k\cos^2 ma}\left(\cos\overline{2ma-2mx'}-\cos 2ma\right)+\frac{3}{8}.\frac{A^2}{k\cos^2 ma}.mx'.\sin\overline{2ma-2mx'}.\cos\overline{2mvt+2B}.\end{aligned}$$

In this case there are sometimes two high waters at every tide.

The law of the rise and fall of the water, at every part of the canal except its mouth, is now different from that which holds on the supposition that the oscillation is small in proportion to the depth of the canal. But the times of high water and of low water are still the same as before, and the high water and the low water are still simultaneous through the whole length of the canal. The second term of the expression above is constant for any given place; the first and third may be represented by $C.\sin\overline{mvt+B}+D.\cos\overline{2mvt+2B}$. In figures 16 and 17 we have represented these expressions by the ordinates of two curves: in fig. 16, $\frac{D}{C}=\frac{1}{6}$; in fig. 17, $\frac{D}{C}=\frac{1}{3}$. In the latter there are two high waters at each tide.

(310.) Problem.—A canal, on whose waters the action of the moon is insensible, communicates at both ends with tidal seas, in which the whole rise of the tide and the corresponding phases of the tide are different: to find the nature of the waves upon it.

Canal between two tidal seas.

(311.) The elevation of the water in the canal will evidently be represented by a combination of *free* tide-waves, of the form $P.\sin\overline{nt-mx+p}+Q.\sin\overline{nt+mx+q}$, or of a form equivalent to this; and the constants must be so determined as to make the elevations at the two extremities of the canal the same as those of the seas. Let a and b be the ordinates of the two extremities of the canal; $A.\sin(nt+\alpha)$ the elevation of the water at one extremity, $B.\sin(nt+\beta)$ that at the other extremity. Then, without going through the whole investigation, it is evident that all the conditions are satisfied by the following expression:

$$K=\frac{A}{\sin\overline{mb-ma}}.\sin\overline{mb-mx}.\sin\overline{nt+\alpha}+\frac{B}{\sin\overline{mb-ma}}.\sin\overline{mx-ma}.\sin\overline{nt+\beta}.$$

The time of high water or low water at any part of the canal will be found by making $\frac{dY}{dt}=0$, from which we obtain

$$\tan nt'=\frac{A\cos\alpha.\sin\overline{mb-mx}+B\cos\beta.\sin\overline{mx-ma}}{A\sin\alpha.\sin\overline{mb-mx}+B\sin\beta.\sin\overline{mx-ma}};$$

and the velocity with which the phase of high water travels along the canal $= \frac{dt'}{dx} =$

$$\frac{m}{n} \cdot \frac{\text{AB} \,.\, \sin \overline{\alpha-\beta} \,.\, \sin \overline{mb-ma}}{\text{A}^2 . \sin^2 \overline{mb-mx} + \text{B}^2 . \sin^2 \overline{mx-ma} + 2\text{AB} . \cos \overline{\alpha-\beta} . \sin \overline{mb-mx} . \sin \overline{mx-ma}}.$$

This expression has the same sign for all values of x; and therefore the high water travels in the same direction along all parts of the canal.

(312.) The expression for K at high water is

$$\frac{1}{\sin \overline{mb-ma}} \sqrt{\{\text{A}^2 . \sin^2 \overline{mb-mx} + \text{B}^2 . \sin^2 \overline{mx-ma} + 2\text{AB} . \cos \overline{\alpha-\beta} . \sin mb-mx . \sin \overline{mx-ma}\}}.$$

If $\overline{mb-ma}$ be nearly $=180°$ and $\overline{\alpha-\beta}$ small, then for all values of x which make $\overline{mb-mx}$ or $\overline{mx-ma}$ not very different from 90°, this value of K may much exceed the values when $x=a$ or $x=b$; that is, the rise of tide in the middle of the canal may be much greater than at its extremities. The velocity of the tide-wave at different points of the canal is inversely as the square of the rise of the tide at those points.

The time and height of high water depend upon the period of the waves.

It is to be remarked, that though in the theory of the tides, (439.) &c., α and β are found to be independent of n, yet m depends on n, and therefore $mb-mx$ and $mx-ma$ depend on n. If, then, the value of n alters, the time of high water determined from the expression for nt', and the height of high water, or K above, will be altered. This is the theorem used by Laplace, and to which reference is made in (121.).

(313.) The general expression for X, corresponding to the general expression for Y (remarking that $\text{Y} = \frac{\text{K}y}{k}$ nearly), is

$$-\frac{\text{A}}{mk . \sin \overline{mb-ma}} \cos \overline{mb-mx} . \sin \overline{nt+\alpha} + \frac{\text{B}}{mk . \sin \overline{mb-ma}} \cos \overline{mx-ma} . \sin \overline{nt+\beta}.$$

This expression vanishes when

$$\tan nt'' = -\frac{-\text{A} \sin \alpha . \cos \overline{mb-mx} + \text{B} \sin \beta . \cos \overline{mx-ma}}{-\text{A} \cos \alpha . \cos \overline{mb-mx} + \text{B} \cos \beta . \cos \overline{mx-ma}}.$$

Thus it appears that the time at which the particles of water are in their mean horizontal position does not coincide with or bear any simple relation to the time at which they have the greatest elevation.

The greatest value of X for any given place (to which the greatest velocity of the particles is proportional) is

$$\frac{1}{mk . \sin \overline{mb-ma}} \sqrt{\{\text{A}^2 . \cos^2 \overline{mb-mx} + \text{B}^2 . \cos^2 \overline{mx-ma} - 2\text{AB} . \cos \overline{\alpha-\beta} . \cos \overline{mb-mx} . \cos \overline{mx-ma}\}}.$$

Canal between a tidal sea and a tideless sea.

(314.) If one of the seas have no tide, let A=0. Then, for high water in every part, $\tan nt' = \cot \beta$, or the high water is simultaneous throughout the canal: the elevation is $\frac{\text{B} . \sin \overline{mx-ma}}{\sin \overline{mb-ma}}$; the greatest value of X is $\frac{\text{B} . \cos \overline{mx-ma}}{mk . \sin \overline{mb-ma}}$, or the water moves most rapidly where the canal joins the tideless sea; and the greatest horizontal displacement occurs at the same instant as the greatest vertical displacement.

Subsection 6.—Theory of Waves on Canals when Friction is taken into account.

(315.) It cannot be supposed that we can give a theory of friction among particles of water, and between water and land, which will pretend to any great degree of exactness. Nevertheless, we can give one of very plausible character, and one which, it is quite certain, will represent *generally* the effects of friction. We conceive that it will be found valuable, as assisting to explain some circumstances of the tides which hitherto have received no explanation.

Friction supposed to be proportional to the velocity.

(316.) It is well known that the resistance to bodies moving in fluids (to which the friction of fluids, running over an uneven surface, is entirely analogous) is nearly proportional to the square of the velocity, when that velocity is considerable. But all experiments have agreed in showing that, when the velocity is small, the resistance is greater than that which is given by this law. In fact, when the velocity is very small, the resistance may be represented as nearly, or more nearly, by supposing it proportional to the first power of the velocity. The velocity of tide-currents, for the most part, is so small that this law may be supposed to apply without great error to them. And it possesses the very great advantage of presenting equations which admit of solution with comparatively little trouble. We shall, therefore, suppose the friction proportional to the velocity, and shall measure it by $f \times$ velocity. And as the velocity (using the same notation which we have throughout employed) is represented by $\frac{d\text{X}}{dt}$, and as the friction tends always to diminish the velocity, and therefore acts backwards when the particles are moving forwards, and acts forwards when the particles are moving backwards, we shall represent the force of friction correctly, in conformity with our supposition, by the expression $-f\frac{dX}{dt}$.

(317.) Confining ourselves to the case of long waves, and supposing the rise and fall of the water to be small in proportion to its depth, we shall have, from the equation of (236.),

$$\frac{d^2X}{dt^2}=F+gk\frac{d^2X}{dx^2},$$

where k is the depth of the water, and F the whole force (independent of the pressure of the water) which acts upon any particle. If, then, the horizontal force produced by external causes is F′, and the force produced by friction is $-f\frac{dX}{dt}$, we must for F put $F'-f\frac{dX}{dt}$, and the equation becomes

$$\frac{d^2X}{dt^2}=F'-f\frac{dX}{dt}+gk\frac{d^2X}{dx^2}$$

or if $gk=v^2$,

$$\frac{d^2X}{dt^2}=F'-f\frac{dX}{dt}+v^2\frac{d^2X}{dx^2}.$$

Investigation when the external force is similar to tidal forces, and there is also friction.

(318.) Problem.—The external force, tending to urge the water of a canal forwards, is represented by $H.\sin\overline{it-mx}$: to find the motion of the water, taking friction into account.

(319.) As the motion for which we desire to obtain an expression is only that which is periodical, and in which the period of the motions is the same as the period of the forces, we must take the most general expression depending upon it which will satisfy the equation. Assume then $X=A.\cos it+B.\sin it$, A and B being functions of x to be discovered. Then $\frac{dX}{dt}=-iA.\sin it+iB.\cos it$; $\frac{d^2X}{dt^2}=-i^2A.\cos it-i^2B.\sin it$; $\frac{d^2X}{dx^2}=\frac{d^2A}{dx^2}.\cos it+\frac{d^2B}{dx^2}.\sin it$. Substituting these in the equation, and putting for F′ its value $H.\sin\overline{it-mx}$, and expanding the sine,

$$\begin{aligned}-i^2A.\cos it-i^2B.\sin it=&\,H.\cos mx.\sin it-H.\sin mx.\cos it\\&+fiA.\sin it-fiB.\cos it\\&+v^2\frac{d^2A}{dx^2}\cos it+v^2\frac{d^2B}{dx^2}\sin it.\end{aligned}$$

As this equation is to hold for all values of it, it will be equivalent to the two following:

$$-i^2A=-H.\sin mx-fiB+v^2\frac{d^2A}{dx^2} \qquad (1.)$$

$$-i^2B=H.\cos mx+fiA+v^2\frac{d^2B}{dx^2}. \qquad (2.)$$

From the former of these,

$$fiB=v^2\frac{d^2A}{dx^2}+i^2A-H.\sin mx \qquad (3.)$$

therefore

$$fi\frac{d^2B}{dx^2}=v^2\frac{d^4A}{dx^4}+i^2\frac{d^2A}{dx^2}+m^2H.\sin mx. \qquad (4.)$$

Multiplying (2.) by fi, and transposing its terms,

$$-fi^3B-fiv^2\frac{d^2B}{dx^2}=f^2i^2A+fiH.\cos mx.$$

Multiplying (3.) by i^2

$$fi^3B=i^2v^2\frac{d^2A}{dx^2}+i^4A-i^2H.\sin mx.$$

Multiplying (4.) by v^2

$$fiv^2\frac{d^2B}{dx^2}=v^4\frac{d^4A}{dx^4}+v^2i^2\frac{d^2A}{dx^2}+v^2m^2H.\sin mx.$$

Adding together the three last equations,

$$0=v^4\frac{d^4A}{dx^4}+2v^2i^2\frac{d^2A}{dx^2}+(i^4+f^2i^2)A+(v^2m^2-i^2)H.\sin mx+fiH.\cos mx.$$

Differential equation for coefficient.

(320.) The equation just found is one of which the solution is well known. Its most general expression is the following. Let the four roots of the equation $0=v^4z^4+2v^2i^2z^2+(i^4+f^2i^2)$ be $\pm p\pm q\sqrt{-1}$: (it is easily found that $p^2=-\frac{i^2}{2v^2}+\sqrt{\left(\frac{i^4+f^2i^2}{4v^4}\right)}$, $q^2=\frac{i^2}{2v^2}+\sqrt{\left(\frac{i^4+f^2i^2}{4v^4}\right)}$:), and put M for $(v^2m^2-i^2)H.\sin mx+fiH.\cos mx$.

Then the expression for A is

$$-\frac{1}{v^4}\varepsilon^{px}.\cos qx\int_x\frac{1}{\cos^2 qx}\int_x\varepsilon^{-2px}.\cos^2 qx\int_x\frac{1}{\cos^2 qx}\int_x\varepsilon^{px}.\cos qx.\,\mathrm{M}.$$

the right hand integration being performed first, and arbitrary constants being added at each integration. But without going through the trouble of this integration, remarking that the part depending on the arbitrary constants will have the form $\mathrm{C}\varepsilon^{px}.\cos qx+\mathrm{C}'\varepsilon^{px}.\sin qx+\mathrm{C}''\varepsilon^{-px}.\cos qx+\mathrm{C}'''\varepsilon^{-px}.\sin qx$ (which may be proved more easily by substitution in the three first terms of the differential equation); and remarking that the substitution of $\frac{\sin mx}{\cos mx}$ in the three first terms will produce $(m^4v^4-2m^2v^2i^2+i^4+f^2i^2)\frac{\sin mx}{\cos mx}$; we easily find for the complete value of A

Solution of differential equation.

$$\frac{(i^2-v^2m^2)\,\mathrm{H}}{v^4m^4-2v^2m^2i^2+i^4+f^2i^2}\sin mx-\frac{fi\,\mathrm{H}}{v^4m^4-2v^2m^2i^2+i^4+f^2i^2}\cos mx$$
$$+\mathrm{C}\,\varepsilon^{px}.\cos qx+\mathrm{C}'\,\varepsilon^{px}.\sin qx+\mathrm{C}''.\varepsilon^{-px}.\cos qx+\mathrm{C}'''.\varepsilon^{-px}.\sin qx.$$

(321.) Substituting this value of A in equation (3.), and remarking that $v^2\frac{d^2}{dx^2}(\varepsilon^{px}.\cos qx)+i^2.\varepsilon^{px}.\cos qx=\varepsilon^{px}\{(p^2v^2-q^2v^2+i^2)\cos qx-2v^2pq.\sin qx\}$: which, on putting for p and q their values, is reduced to $-fi\,\varepsilon^{px}.\sin qx$; we obtain

$$fi\,\mathrm{B}=\frac{(i^2-v^2m^2)^2.\,\mathrm{H}}{v^4m^4-2v^2m^2i^2+i^4+f^2i^2}\sin mx-\mathrm{H}\sin mx-\frac{fi\,(i^2-v^2m^2)\,\mathrm{H}}{v^4m^4-2v^2m^2i^2+i^4+f^2i^2}\cos mx$$
$$+fi\,\{-\mathrm{C}.\varepsilon^{px}.\sin qx+\mathrm{C}'.\varepsilon^{px}.\cos qx+\mathrm{C}''.\varepsilon^{-px}\sin qx-\mathrm{C}'''.\varepsilon^{-px}.\cos qx\},$$

or

$$\mathrm{B}=\frac{-fi\,\mathrm{H}}{v^4m^4-2v^2m^2i^2+i^4+f^2i^2}\sin mx-\frac{(i^2-v^2m^2)\,\mathrm{H}}{v^4m^4-2v^2m^2i^2+i^4+f^2i^2}\cos mx$$
$$-\mathrm{C}.\varepsilon^{px}.\sin qx+\mathrm{C}'.\varepsilon^{px}.\cos qx+\mathrm{C}''.\varepsilon^{-px}.\sin qx-\mathrm{C}'''.\varepsilon^{-px}.\cos qx,$$

and finally $\mathrm{X}=\mathrm{A}\cos it+\mathrm{B}\sin it=$

Expression for displacement of particles.

$$\frac{-(i^2-v^2m^2)\,\mathrm{H}}{(i^2-v^2m^2)^2+f^2i^2}\sin\overline{it-mx}-\frac{fi\,\mathrm{H}}{(i^2-v^2m^2)^2+f^2i^2}\cos\overline{it-mx}+\varepsilon^{px}\{\mathrm{C}.\cos\overline{it+qx}+\mathrm{C}'.\sin\overline{it+qx}\}$$
$$+\varepsilon^{-px}\{\mathrm{C}''.\cos\overline{it-qx}-\mathrm{C}'''.\sin\overline{it-qx}\}.$$

We shall now proceed to apply this expression to some particular cases.

Canal supposed indefinite, or returning into itself.

(322.) Problem.—To find the expression for the disturbance in a canal of indefinite length, or one returning into itself (as a canal surrounding the earth).

Here it is plain that we cannot have any of the terms multiplying ε^{px} and ε^{-px}, because, in the case of a returning canal, these terms would have different values on returning by a different number of circuits to the same spot. Hence

$$\mathrm{X}=\frac{-\mathrm{H}}{(i^2-v^2m^2)^2+f^2i^2}\{(i^2-v^2m^2).\sin\overline{it-mx}+fi.\cos\overline{it-mx}\}.$$

If $\tan\mathrm{D}=\frac{fi}{i^2-v^2m^2}$,

$$\mathrm{X}=\frac{-\mathrm{H}}{\sqrt{\{(i^2-v^2m^2)^2+f^2i^2\}}}\sin\overline{it-mx+\mathrm{D}}.$$

Upon this we have to remark as follows:

(323.) 1st. This expression never becomes infinite. It is greatest nearly when $i^2-v^2m^2=0$, or $i^2-gkm^2=0$. Then $\mathrm{D}=90^\circ$, and the expression for X is $\frac{-\mathrm{H}}{fi}\cos\overline{it-mx}$, which is very large if f is small.

(324.) 2nd. The expression for X is always less than that which is obtained by making f the coefficient of friction $=0$.

(325.) 3rd. The expression for V, the whole depth at any point in the disturbed state, is $\frac{k}{1+\frac{d\mathrm{X}}{dx}}=k-k\frac{d\mathrm{X}}{dx}$ nearly, and the fluctuation in height, or K, is therefore $-k\frac{d\mathrm{X}}{dx}$

$$=\frac{-km\mathrm{H}}{(i^2-v^2m^2)^2+f^2i^2}\{(i^2-v^2m^2).\cos\overline{it-mx}-fi.\sin\overline{it-mx}\}$$
$$=\frac{-km\mathrm{H}}{\sqrt{\{(i^2-v^2m^2)^2+f^2i^2\}}}\cos\overline{it-mx+\mathrm{D}}.$$

Tide is accelerated by friction.

This is maximum, or it is high water, when $it-mx+\mathrm{D}=\pi$, or when $t=\frac{\pi+mx-\mathrm{D}}{i}$. The force at the point in question vanishes, and the force on each side tends to draw the water towards the place, when $t=\frac{mx}{i}$. Consequently, high water follows the time of the force vanishing by $\frac{\pi-\mathrm{D}}{i}$. As the interval between high water and low water is $\frac{\pi}{i}$, it appears that high water is the next conspicuous phase which follows the evanescence of forces.

The acceleration is greater for a tide of longer period.

(326.) It appears here that high water is *accelerated* by the time $\frac{\mathrm{D}}{i}$, or $\frac{f}{i^2-v^2m^2}$ nearly. If then there were two forces acting at the same time, one depending upon $\overline{it-mx}$ and the other depending upon $\overline{(i-i'')t-mx}$, the tide depending upon the former would be accelerated by $\frac{f}{i^2-v^2m^2}$, and that depending upon the latter by $\frac{f}{(i-i'')^2-v^2m^2}$. The tide, therefore, depending upon $\overline{(i-i'')t-mx}$ would be more accelerated that that depending upon $\overline{it-mx}$ by $\frac{f}{(i-i'')^2-v^2m^2}-\frac{f}{i^2-v^2m^2}$, or (if i'' be small) $f\times\frac{2ii''}{(i^2-v^2m^2)^2}$. If $i^2-v^2m^2$ be small, this may be large enough to be very sensible. We shall hereafter find that this conclusion is most important.

(327.) 4th. If the water be so deep that v^2m^2 or gkm^2 is greater than i^2, the fluctuation in height or $-k\frac{d\mathrm{X}}{dx}=\frac{km\mathrm{H}}{(v^2m^2-i^2)^2+f^2i^2}\{(v^2m^2-i^2).\cos\overline{it-mx}+fi.\sin\overline{it-mx}\}$. Making $\tan \mathrm{D}'=\frac{fi}{v^2m^2-i^2}$, this becomes $\frac{km\mathrm{H}}{\sqrt{\{(v^2m^2-i^2)^2+f^2i^2\}}}\cos\overline{it-mx-\mathrm{D}'}$. This is maximum, or it is high water, when $it-mx-\mathrm{D}'=0$, or $t=\frac{mx+\mathrm{D}'}{i}$, which follows the time of evanescence of the forces by $\frac{\mathrm{D}'}{i}$. In all cases, therefore, the conspicuous phase which next follows the evanescence of forces is high water.

Coefficient of force supposed variable.

(328.) 5th. Suppose the coefficient of force to be variable and equal to $\mathrm{H}+\mathrm{H}'.\cos i't$, i' being small. Then the force $=(\mathrm{H}+\mathrm{H}'.\cos i't).\sin\overline{it-mx}=\mathrm{H}.\sin\overline{it-mx}+\frac{\mathrm{H}'}{2}\sin\overline{(i+i')t-mx}+\frac{\mathrm{H}'}{2}\sin\overline{(i-i')t-mx}$, and the expression for K is

$$\frac{-km\mathrm{H}}{(i^2-v^2m^2)^2+f^2i^2}\{(i^2-v^2m^2).\cos\overline{it-mx}-fi.\sin\overline{it-mx}\}$$
$$-\frac{km\mathrm{H}'}{\{(i+i')^2-v^2m^2\}^2+f^2.(i+i')^2}.\frac{1}{2}\left\{\{(i+i')^2-v^2m^2\}.\cos\overline{(i+i')t-mx}-f(i+i').\sin\overline{(i+i')t-mx}\right\}$$
$$-\frac{km\mathrm{H}'}{\{(i-i')^2-v^2m^2\}^2+f^2.(i-i')^2}.\frac{1}{2}\left\{\{(i-i')^2-v^2m^2\}.\cos\overline{(i-i')t-mx}-f(i-i')\sin.\overline{(i-i')t-mx}\right\}.$$

Suppose f so small that its square may be neglected. Then K becomes

$$-\frac{km\mathrm{H}}{i^2-v^2m^2}\cos\overline{it-mx}+\frac{kfim\mathrm{H}}{(i^2-v^2m^2)^2}\sin\overline{it-mx}$$
$$-\frac{1}{2}.\frac{km\mathrm{H}'}{\{(i+i')\}^2-v^2m^2}\cos\overline{(i+i')t-mx}+\frac{1}{2}.\frac{kf(i+i')m\mathrm{H}'}{\{(i+i')^2-v^2m^2\}^2}\sin\overline{(i+i')t-mx}$$
$$-\frac{1}{2}.\frac{km\mathrm{H}'}{\{(i-i')\}^2-v^2m^2}\cos\overline{(i-i')t-mx}+\frac{1}{2}.\frac{kf(i-i')m\mathrm{H}'}{\{(i-i')^2-v^2m^2\}^2}\sin\overline{(i-i')t-mx}.$$

Expanding these expressions to the first power of i', and omitting the general multiplier $\frac{km\mathrm{H}}{i^2-v^2m^2}$, the whole may be put in the following form.

$$\left\{-1-\frac{\mathrm{H}'}{\mathrm{H}}\cos i't-f\frac{\mathrm{H}'}{\mathrm{H}}.\frac{i'(3i^2+v^2m^2)}{(i^2-v^2m^2)^2}\sin i't\right\}\cos\overline{it-mx}$$
$$+\left\{-2\frac{\mathrm{H}'}{\mathrm{H}}.\frac{ii'}{i^2-v^2m^2}\sin i't+\frac{fi}{i^2-v^2m^2}+\frac{\mathrm{H}'}{\mathrm{H}}.\frac{fi}{i^2-v^2m^2}\cos i't\right\}\sin\overline{it-mx}.$$

(329.) On any given day (in treating of the tides) $i't$ may be considered nearly constant. Regarding the coefficients of $\cos\overline{it-mx}$ and $\sin\overline{it-mx}$ therefore as constant, the greatest elevation and depression of the water on that day will be expressed by the square root of the sums of their squares. Expanding the squares on the supposition that $\frac{H'}{H}$ is small, and taking only the first power of $\frac{H'}{H}$, the first power of f, the first power of i', and the combination of these first powers (a process which is legitimate for showing the combined effect of friction and variable coefficient, although the square of any one of these quantities is rejected), we have for the square of elevation or depression

$$1+\frac{2H'}{H}\cos i't+2f\frac{H'}{H}\,\frac{i'(3i^2+v^2m^2)}{(i^2-v^2m^2)^2}\sin i't-4f\frac{H'}{H}\cdot\frac{i^2i'}{(i^2-v^2m^2)^2}\sin i't$$

$$=1+\frac{2H'}{H}\cos i't+2f\frac{H'}{H}\cdot\frac{i'(i^2+v^2m^2)}{(i^2-v^2m^2)^2}\sin i't,$$

and the expression for the greatest elevation or depression, restoring the factor, is

$$-\frac{kmH}{i^2-v^2m^2}\left\{1+\frac{H'}{H}\cos i't+f\frac{H'}{H}\cdot\frac{i'(i^2+v^2m^2)}{(i^2-v^2m^2)^2}\sin i't\right\}.$$

The day on which the rise or fall is greatest is determined by making the quantity within the brackets maximum, or making $\cos i't+\frac{fi'(i^2+v^2m^2)}{(i^2-v^2m^2)^2}\sin i't$ maximum. This will be when $\tan i't$ or $i't=\frac{fi'(i^2+v^2m^2)}{(i^2-v^2m^2)^2}$, or when $t=\frac{f(i^2+v^2m^2)}{(i^2-v^2m^2)^2}$. But the variable force is greatest when $t=0$: Therefore the greatest tide follows the greatest force by the time $\frac{f(i^2+v^2m^2)}{(i^2-v^2m^2)^2}$. This appears to us an important result, and one which no other theory has obtained. The equilibrium-theory of tides necessarily makes the tides to be greatest upon the same day on which the force is greatest. Laplace's theory (93.), and the theory of waves in canals without friction (288.), give the same result. But here we find a retardation accounted for by friction; and moreover this retardation is considerable. For the alteration in the time of any high water was found (326.) to be $\frac{D}{i}$, or $\frac{f}{i^2-v^2m^2}$: here the retardation in the time of the greatest tide is $\frac{f(i^2+v^2m^2)}{(i^2-v^2m^2)^2}$, or is equal to the alteration in the time of high water $\times\frac{i^2+v^2m^2}{i^2-v^2m^2}$. When i^2 is not much greater than v^2m^2 or gkm^2, or when the depth is not much less than that in which the free wave would move as rapidly as the forced wave, this multiplier may be considerable, and (for the tides) the retardation may amount to one or several days.

Greatest tide occurs some time later than the greatest force.

(330.) If the term $H=0$, or if the coefficient of force be merely $H'.\cos i't$, the expression for K is

$$\frac{kmH'}{2}\left\{\left(-\frac{1}{(i-i')^2-v^2m^2}-\frac{1}{(i+i')^2-v^2m^2}\right)\cos i't+\left(-\frac{f(i-i')}{\{(i-i')^2-v^2m^2\}^2}+\frac{f(i+i')}{\{(i+i')^2-v^2m^2\}^2}\right)\sin i't\right\}\cos\overline{it-mx}$$

$$+\frac{kmH'}{2}\left\{\left(-\frac{1}{(i-i')^2-v^2m^2}+\frac{1}{(i+i')^2-v^2m^2}\right)\sin i't+\left(\frac{f(i-i')}{\{(i-i')^2-v^2m^2\}^2}+\frac{f(i+i)}{\{(i+i')^2-v^2m^2\}^2}\right)\cos i't\right\}\sin\overline{it-mx}.$$

If i' be small, this is nearly

$$\frac{kmH'}{i^2-v^2m^2}\left\{-\cos i't-f.\frac{i'(3i^2+v^2m^2)}{(i^2-v^2m^2)^2}\sin i't\right\}\cos\overline{it-mx}$$

$$+\frac{kmH'}{i^2-v^2m^2}\left\{\frac{-2ii'}{i^2-v^2m^2}\sin i't+\frac{fi}{i^2-v^2m^2}\cos i't\right\}\sin\overline{it-mx}.$$

The square of the elevation or depression upon any day (regarding $i't$ as constant) is the sum of the squares of the coefficients of $\cos\overline{it-mx}$ and $\sin\overline{it-mx}$; which, omitting the factor $\frac{kmH'}{i^2-v^2m^2}$, and taking only the first power of f, is

$$\cos^2 i't+\frac{4i^2i'^2}{(i^2-v^2m^2)^2}\sin^2 i't+f\left\{\frac{2i'(3i^2+v^2m^2)}{(i^2-v^2m^2)^2}-\frac{4i^2i'}{(i^2-v^2m^2)^2}\right\}\sin i't.\cos i't$$

of which the second term, as depending on the square of i' is to be omitted. Thus the expression becomes

$$\cos^2 i't+f.\frac{2i'(i^2+v^2m^2)}{(i^2-v^2m^2)^2}\sin i't\ \cos i't$$

or

$$\tfrac{1}{2}+\tfrac{1}{2}\cos 2i't+\frac{fi'(i^2+v^2m^2)}{(i^2-v^2m^2)^2}\sin 2i't;$$

whose maximum value occurs when $\tan 2i't$ or $2i't=\frac{2fi'(i^2+v^2m^2)}{(i^2-v^2m^2)^2}$, or $t=\frac{f(i^2+v^2m^2)}{(i^2-v^2m^2)^2}$, as before.

(331.) It is to be remarked that the slower the recurrence of the tide is in proportion to the space which it passes over (that is, the smaller i is in proportion to vm), the greater is the retardation. Thus the lunar tide is more retarded than the solar tide.

We shall now consider some cases in which the limits enter.

Tide propagated up a river, when there is friction.

(332.) Problem.—To find the nature of the tides propagated up a river of indefinite length communicating with a tidal sea, friction being considered, but no tidal forces being supposed to act on the river.

Here we must take the general solution of (321.) on the supposition that the force is 0, and we find for the general expression for X,

$$\varepsilon^{px}\{C.\cos\overline{it+qx}+C'.\sin\overline{it+qx}\}+\varepsilon^{-px}\{C''.\cos\overline{it-qx}-C'''.\sin\overline{it-qx}\}$$

where p^2 and q^2 have the values given in (320.).

As we suppose our wave to be propagated from the sea, and to meet with nothing which reflects it, we must take only those terms which depend on $it-qx$, and therefore X becomes

$$\varepsilon^{-px}\{C''.\cos\overline{it-qx}-C'''.\sin\overline{it-qx}\}.$$

From this,
$$\frac{dX}{dx}=\varepsilon^{-px}\{(-pC''+qC''').\cos\overline{it-qx}+(qC''+pC''').\sin\overline{it-qx}\},$$

and
$$K=-k\frac{dX}{dx}\text{ nearly }=k\varepsilon^{-px}.\{(pC''-qC''').\cos\overline{it-qx}+(-qC''-pC''').\sin\overline{it-qx}\}.$$

At the sea, or where $x=0$, this becomes $k\{(pC''-qC''').\cos it+(-qC''-pC''').\sin it\}$. If we suppose the tidal elevation of the sea to be expressed by $A.\sin nt$, we must have $i=n$, $k(pC''-qC''')=0$, $k(-qC''-pC''')=A$. Substituting these in the general expression for K,

$$K=A\varepsilon^{-px}.\sin\overline{nt-qx},$$

p and q having the values obtained by putting n for i. And $C''=\dfrac{-qA}{k(p^2+q^2)}$, $C'''=\dfrac{-pA}{k(p^2+q^2)}$; therefore

$$X=\frac{A}{k(p^2+q^2)}\varepsilon^{-px}.\{-q.\cos\overline{nt-qx}+p.\sin\overline{nt-qx}\}.$$

Tidal disturbance gradually diminishes in going up the river.

These expressions indicate a wave whose vertical elevation and horizontal motion of particles diminish continually as it travels up the river. The value of $\dfrac{dX}{dt}$ or the velocity of the water is,

$$\frac{nA}{k(p^2+q^2)}.\varepsilon^{-px}.\{q.\sin\overline{nt-qx}+p.\cos\overline{nt-qx}\}.$$

The flow ceases before the water has dropped to mean height.

Now high water occurs when $\sin\overline{nt-qx}$ has its greatest positive value, or $nt-qx=90°$; the next mean elevation will occur then when $nt-qx=180°$; at this time the velocity of the water $=-\dfrac{nA}{k(p^2+q^2)}\varepsilon^{-px}.p$; or the water will be flowing downwards; and therefore the direction of tide-current changes sooner after high water than if there were no friction.

Tide in a river stopped by a barrier, considering friction.

(333.) Problem.—To find the nature of the tides in the river when there is a barrier at a certain distance a from the mouth; other suppositions being as before.

In this case, taking the general solution, we cannot reject the first terms, because there may be a reflected wave. And, moreover, without taking these first terms, we shall not have a sufficient number of arbitrary constants for our conditions. These conditions are, that when $x=0$, K must $=A\sin nt$, and when $x=a$, X must $=0$; for all values of t. Assume then

$$X=\varepsilon^{px}\{C.\cos\overline{it+qx}+C'.\sin\overline{it+qx}\}+\varepsilon^{-px}.\{C''.\cos\overline{it-qx}-C'''.\sin\overline{it-qx}\}$$
$$K=-k\frac{dX}{dx}=-k\varepsilon^{px}\{(pC+qC').\cos\overline{it+qx}+(-qC+pC').\sin\overline{it+qx}\}$$
$$-k\varepsilon^{-px}\{(-pC''+qC''').\cos\overline{it-qx}+(qC''+pC''').\sin\overline{it-qx}\}.$$

When $x=0$, K becomes

$$-k\{(pC+qC').\cos it+(-qC+pC').\sin it\}-k\{(-pC''+qC''').\cos it+(qC''+pC''').\sin it\}.$$

The first condition therefore requires

$$i=n$$
$$pC+qC'-pC''+qC'''=0$$
$$-k\{-qC+pC'+qC''+pC'''\}=A.$$

The second condition requires

$$\varepsilon^{pa}.\{\quad C.\cos qa+C'.\sin qa\}+\varepsilon^{-pa}.\{C''.\cos qa+C'''.\sin qa\}=0$$
$$\varepsilon^{pa}\ \{-C.\sin qa+C'.\cos qa\}+\varepsilon^{-pa}.\{C''.\sin qa-C'''\ \cos qa\}=0.$$

Determining from the last four equations the values of C, C′, C″, C‴, and substituting them in the expressions for X and K, we find

$$K=\frac{A}{\sqrt{\{\varepsilon^{2pa}+\varepsilon^{-2pa}+2\cos 2qa\}}}\times\{\varepsilon^{px-pa}.\sin\overline{it+qx-E}+\varepsilon^{pa-px}.\sin\overline{it-qx+F}\}$$

where $\tan E=\frac{\sin 2qa}{\varepsilon^{-2pa}+\cos 2qa}$, $\tan F=\frac{\sin 2qa}{\varepsilon^{2pa}+\cos 2qa}$, and therefore $E+F=2qa$.

Putting the quantity within the brackets under the form,

$$\cos it\times\{\varepsilon^{px-pa}.\sin\overline{qx-E}-\varepsilon^{pa-px}.\sin\overline{qx-F}\}+\sin it\times\{\varepsilon^{px-pa}.\cos\overline{qx-E}+\varepsilon^{pa-px}.\cos\overline{qx-F}\}$$

$$=P.\cos it+Q.\sin it=\sqrt{P^2+Q^2}.\left\{\frac{P}{\sqrt{(P^2+Q^2)}}\cos it+\frac{Q}{\sqrt{(P^2+Q^2)}}\sin it\right\},$$

and making $\frac{Q}{P}=\tan D$, this becomes

$$\sqrt{P^2+Q^2}.\cos\overline{it-D};$$

and, substituting for P and Q,

$$K=A\sqrt{\frac{\varepsilon^{2px-2pa}+\varepsilon^{2pa-2px}+2\cos\overline{2qa-2qx}}{\varepsilon^{2pa}+\varepsilon^{-2pa}+2\cos 2qa}}\times\cos\overline{it-D}.$$

(334.) At any given point of the river, the greatest elevation or depression of the water is the coefficient of $\cos\overline{it-D}$. This coefficient cannot, with any values of x and a, be infinite; and in this respect the result now found differs from that found in (307.) without friction. The numerator of K increases as x increases, only when $4q.\sin\overline{2qa-2qx}$ is greater than $2p\ (\varepsilon^{2pa-2px}-\varepsilon^{2px-2pa})$; which differs from the result of (307.). The time t' of high water at any place will be determined by making $t'=\frac{D}{i}$, and the reciprocal of the velocity with which the phase of high water travels up the river will be $\frac{1}{i}.\frac{dD}{dx}$. Since $\tan D=\frac{Q}{P}$, $\frac{dD}{dx}=\frac{P\frac{dQ}{dx}-Q\frac{dP}{dx}}{P^2+Q^2}$. Putting for P and Q their values, we find for the reciprocal of the velocity of the phase of high water,

$$\frac{1}{i}.\frac{q(\varepsilon^{2pa-2px}-\varepsilon^{2px-2pa})+2p.\sin\overline{2qa-2qx}}{\varepsilon^{2pa-2px}+\varepsilon^{2px-2pa}+2\cos\overline{2qa-2qx}}.$$

Wave travels up the river.

This quantity is always positive $\left(\text{for even when } 2qa-2qx=\frac{3\pi}{2}\text{, which gives the second term its greatest negative value } -2p\text{, the two first terms } =q\left(\varepsilon^{\frac{3\pi p}{2q}}-\varepsilon^{\frac{-3\pi p}{2q}}\right)=3\pi p+\&c.\right)$. Thus, in all cases, there is a wave rolling up the river. This result is different from that of (307.), as found without supposing friction.

(335.) The value of X, found in the same manner, is

$$\frac{A}{k\sqrt{(p^2+q^2)}\sqrt{(\varepsilon^{2pa}+\varepsilon^{-2pa}+2\cos 2qa)}}+\{\varepsilon^{px-pa}.\cos\overline{it+qx-G}-\varepsilon^{pa-px}.\cos\overline{it-qx-H}\},$$

when $\tan G=\frac{-p-p\varepsilon^{2pa}.\cos 2qa+q\varepsilon^{2pa}.\sin 2qa}{q+p\varepsilon^{2pa}.\sin 2qa+q\varepsilon^{2pa}.\cos 2qa}$, $\tan H=\frac{p\varepsilon^{4pa}+p\varepsilon^{2pa}.\cos 2qa+q\varepsilon^{2pa}.\sin 2qa}{-q\varepsilon^{4pa}+p\varepsilon^{2pa}.\sin 2qa-q\varepsilon^{2pa}.\cos 2qa}$.

Putting the quantity within the brackets, or

$$\cos it\times(\varepsilon^{px-pa}.\cos\overline{qx-G}-\varepsilon^{pa-px}.\cos\overline{qx+H})-\sin it\times(\varepsilon^{px-pa}.\sin\overline{qx-G}+\varepsilon^{pa-px}.\sin\overline{qx+H}),$$

into the form

$$P'.\cos it-Q'.\sin it=\sqrt{P'^2+Q'^2}.\cos\overline{it+D'},\ \text{where } \tan D'=\frac{Q'}{P'},$$

and remarking that $H-G=-2qa$, the expression for X becomes

$$\frac{A}{k}\sqrt{\frac{\varepsilon^{2pa-2px}+\varepsilon^{2px-2pa}-2\cos\overline{2qa-2qx}}{(p^2+q^2)(\varepsilon^{2pa}+\varepsilon^{-2pa}+2\cos 2qa)}}\times\cos\overline{it+D'}.$$

The time at which, for any given place, the water has its greatest horizontal displacement up the river (or the time when the flow ceases and the ebb commences) is therefore $-\frac{D'}{i}$. But we have found for the time of high water $\frac{D}{i}$. Therefore the end of flow follows high water by $-\frac{1}{i}(D'+D)$.

Now
$$\tan(D'+D)=\frac{P'Q+PQ'}{PP'-QQ'}=\frac{-(\varepsilon^{2pa-2px}-\varepsilon^{2px-2pa})+2\sin\overline{2qa-2qx}.\tan\overline{E-G}}{(\varepsilon^{2pa-2px}-\varepsilon^{2px-2pa})\tan\overline{E-G}+2\sin\overline{2qa-2qx}}.$$

Putting for tan E and tan G their values, it is easily found that $\tan\overline{E-G}=\frac{p}{q}$; therefore
$$\tan(-D'-D)=\frac{q(\varepsilon^{2pa-2px}-\varepsilon^{2px-2pa})-2p.\sin\overline{2qa-2qx}}{p(\varepsilon^{2pa-2px}-\varepsilon^{2px-2pa})+2q.\sin\overline{2qa-2qx}}.$$

End of flow follows high water very soon.

Both numerator and denominator of this expression are positive, and therefore the end of flow *follows* high water. But near the mouth of the river $\varepsilon^{2pa-2px}-\varepsilon^{2px-2pa}$ is reduced to $\varepsilon^{2pa}-\varepsilon^{-2pa}$ nearly, which is large, and the numerator is therefore large, or the end of flow follows high water by a considerable time. Near the barrier, $\varepsilon^{2pa-2px}-\varepsilon^{2px-2pa}$ becomes $4(pa-px)$ nearly, and $\sin\overline{2qa-2qx}$ becomes $2qa-2qx$ nearly, and the numerator is therefore very small, or the end of flow follows the high water very closely.

Tides in a canal bounded at both ends, considering friction.

(336.) Problem.—The external force $H.\sin\overline{it-mx}$ acts upon the waters of a canal which is bounded at both ends: to find the motion of the water, taking friction into account.

Here we must use the general solution of (321). It gives
$$X=L.\cos\overline{it-mx}+M.\sin\overline{it-mx}+\varepsilon^{px}\{C.\cos\overline{it-qx}+C'.\sin\overline{it+qx}\}+\varepsilon^{-px}\{C''.\cos\overline{it-qx}-C'''.\sin\overline{it-qx}\};$$
where L, M, p, q, are the constants whose values are to be found in (320.), and where C, C′, C″, C‴, are arbitrary. Let α and β be the two values of x at the boundaries of the canal. Then the conditions by which the values of C, C′, C″, C‴, are to be determined are that, for all values of t, $X=0$ when $x=\alpha$, and when $x=\beta$.

(337.) The elimination presents no difficulty, and leads to the following expression. Let $\varepsilon^{2p\alpha-2p\beta}-2\cos\overline{2q\alpha-2q\beta}+\varepsilon^{2p\beta-2p\alpha}=B$; then X=
$$\begin{aligned}
&L\cos\overline{it-mx}+M\sin\overline{it-mx}\\
&+\frac{L}{B}(-\varepsilon^{px+p\alpha-2p\beta}.\cos\overline{it+qx-m\alpha-q\alpha}+\varepsilon^{px-p\beta}.\cos\overline{it+qx-m\beta+q\beta-2q\alpha}+\varepsilon^{px-p\alpha}.\cos\overline{it+qx-m\alpha+q\alpha-2q\beta}\\
&\qquad-\varepsilon^{px-2p\alpha+p\beta}\cos\overline{it+qx-m\beta-q\beta})\\
&+\frac{M}{B}(-\varepsilon^{px+p\alpha-2p\beta}.\sin\overline{it+qx-m\alpha-q\alpha}+\varepsilon^{px-p\beta}.\sin\overline{it+qx-2q\alpha-m\beta+q\beta}+\varepsilon^{px-p\alpha}.\sin\overline{it+qx-m\alpha+q\alpha-2q\beta}\\
&\qquad-\varepsilon^{px-2p\alpha+p\beta}.\sin\overline{it+qx-m\beta-q\beta})\\
&+\frac{L}{B}(-\varepsilon^{-px-p\alpha+2p\beta}.\cos\overline{it-qx-m\alpha+q\alpha}+\varepsilon^{-px+p\beta}.\cos\overline{it-qx+2q\alpha-m\beta-q\beta}+\varepsilon^{-px+p\alpha}.\cos\overline{it-qx-m\alpha-q\alpha+2q\beta}\\
&\qquad-\varepsilon^{-px+2p\alpha-p\beta}.\cos\overline{it-qx-m\beta+q\beta})\\
&+\frac{M}{B}(-\varepsilon^{-px-p\alpha+2p\beta}.\sin\overline{it-qx-m\alpha+q\alpha}+\varepsilon^{-px+p\beta}.\sin\overline{it-qx+2q\alpha-m\beta-q\beta}+\varepsilon^{-px+p\alpha}.\sin\overline{it-qx-m\alpha-q\alpha+2q\beta}\\
&\qquad-\varepsilon^{-px+2p\alpha-p\beta}.\sin\overline{it-qx-m\beta+q\beta})
\end{aligned}$$
from which the expression for K will readily be inferred by observing that $K=-k\frac{dX}{dx}$; and that
$$-k\frac{d}{dx}(\varepsilon^{px+a}.\cos\overline{b+qx})=-k.\varepsilon^{px+a}.(p\cos\overline{b+qx}-q\sin\overline{b+qx})=-k\sqrt{p^2+q^2}.\varepsilon^{px+a}.\cos\overline{b+qx+c},\text{ where }\tan c=\frac{q}{p}.$$
The application of c is the same throughout (since $-p$ is accompanied by $-q$); but for $-p$, the sign of the multiplier $\sqrt{p^2+q^2}$ must be changed.

(338.) The purport of this expression will be best understood by examining the state of motion of the water at the middle of the canal and at one end, its length being supposed considerable. Suppose $\alpha>\beta$; the value of the divisor B will be nearly $\varepsilon^{2p\alpha-2p\beta}$. First suppose $x=\frac{\alpha+\beta}{2}$; then $\varepsilon^{px+p\alpha-2p\beta}=\varepsilon^{\frac{3p}{2}(\alpha-\beta)}$; when divided by B the quotient will be $\varepsilon^{-\frac{p}{2}(\alpha-\beta)}$; and as $\alpha-\beta$ is large, this term will be small. In like manner all the other terms will be small; and thus, near the middle of the canal, the expressions will be reduced to their first terms,
$$X=L.\cos\overline{it-mx}+M.\sin\overline{it-mx},\qquad K=-kmL.\sin\overline{it-mx}+kmM.\cos\overline{it-mx},$$
which are the same as if the canal were indefinitely long. Secondly, suppose $x=\alpha$; then $\varepsilon^{px+p\alpha-2p\beta}=\varepsilon^{2p\alpha-2p\beta}$; when divided by B the quotient is 1; this term therefore is sensible; but no other term is in the same predicament. Hence, near the end of the canal, we have only to consider the following terms in X;

The tidal motion is greater at the ends than in the middle.

$$L.\cos\overline{it-mx}+M.\sin\overline{it-mx}-\frac{L}{B}\varepsilon^{px+p\alpha-2p\beta}.\cos\overline{it+qx-m\alpha-q\alpha}-\frac{M}{B}\varepsilon^{px+p\alpha-2p\beta}.\sin\overline{it+qx-m\alpha-q\alpha};$$
from which (remarking that p is small and q is not small),

$$K=-k\frac{dX}{dx}=-kmL.\sin\overline{it-mx}+kmM.\cos\overline{it-mx}-\frac{kqL}{B}\varepsilon^{px+p\alpha-2p\beta}.\sin\overline{it+qx-m\alpha-q\alpha}$$
$$+\frac{kqM}{B}\varepsilon^{px+p\alpha-2p\beta}.\cos\overline{it+qx-m\alpha-q\alpha}.$$

Putting α for x and $\varepsilon^{2p\alpha-2p\beta}$ for B, this becomes

$$K=-kL\,(m+q).\sin\overline{it-m\alpha}+kM\,(m+q).\cos\overline{it-m\alpha},$$

or the vertical tide at the end of the canal is greater than that in the middle in the proportion of $m+q : m$.

A different form of arbitrary function sometimes necessary

(339.) The solution which applied to the several Problems which we have just terminated was founded essentially upon the assumption that the motions of the water recur with the same magnitude when it has changed by 2π. But it may happen that, even if there are oscillations, they may not recur with the same magnitude, but may continually decrease. This assumption will not affect that part of the solution in (321.) which depends on $\sin\overline{it-mx}$ and $\cos\overline{it-mx}$; but it will affect the terms which are multiplied by arbitrary constants. We shall now undertake this investigation. To find whether the equation $\frac{d^2X}{dt^2}=-f\frac{dX}{dt}+v^2\frac{d^2X}{dx^2}$ can be satisfied by the assumption $X=C.\varepsilon^{rt+sx}.\cos\overline{ut+wx+C'}$.

(340.) Differentiating, we have

$$\frac{dX}{dt}=C.\varepsilon^{rt+sx}\left(r.\cos\overline{ut+wx+C'}-u.\sin\overline{ut+wx+C'}\right)$$
$$\frac{d^2X}{dt^2}=C.\varepsilon^{rt+sx}\left((r^2-u^2).\cos\overline{ut+wx+C'}-2ru.\sin\overline{ut+wx+C'}\right)$$
$$\frac{d^2X}{dx^2}=C.\varepsilon^{rt+sx}\left((s^2-w^2).\cos\overline{ut+wx+C'}-2sw.\sin\overline{ut+wx+C'}\right)$$

Substituting in the equation,

$$(r^2-u^2).\cos\overline{ut+wx+C'}-2ru.\sin\overline{ut+wx+C'}=$$
$$-fr.\cos\overline{ut+wx+C'}+fu.\sin\overline{ut+wx+C'}+v^2(s^2-w^2).\cos\overline{ut+wx+C'}-2v^2sw.\sin\overline{ut+wx+C'}.$$

As this is to be true for all values of t and of x, it must hold for the separated coefficients of the sine and cosine; or

$$r^2-u^2=-fr+v^2(s^2-w^2);\qquad -2ru=fu-2v^2sw,$$

leaving C and C′ indeterminate. When the values of two of the quantities r, s, v, w, are fixed by the conditions of any Problem, the values of the other two can be found from these equations.

Tides on a current river, considering friction.

(341.) Problem.—A river of indefinite length runs on a declivity towards a tidal sea: to investigate the motion of its waters; its mean depth being uniform, and friction being taken into account.

Take for the axis of x a line drawn along the bottom of the river. It will be inclined to the horizon by a very small angle α. Resolve the force of gravity into one part perpendicular to the bottom of the river and one part parallel to it. The former will not sensibly differ from g; the latter will $=g\sin\alpha$. And (measuring x, as in all other cases, up the river) this force tends to diminish x, or is $=-g\sin\alpha$. Hence the general equation becomes

$$\frac{d^2X}{dt^2}=-g\sin\alpha-f\frac{dX}{dt}+v^2\frac{d^2X}{dx^2}.$$

A solution of this is, $X=-\frac{g\sin\alpha}{f}t$, which we will call $-bt$. (It is evident that this term alone denotes that the water will run towards the sea with a uniform velocity.) The most general solution then, which is adapted to our purposes, is

$$X=-bt+\text{ the general solution of the equation }\frac{d^2X}{dt^2}=-f\frac{dX}{dt}+v^2\frac{d^2X}{dx^2},$$

or $$X=-bt+C\varepsilon^{rt+sx}.\cos(ut+wx+C'),$$

where $$r^2-u^2=-fr+v^2(s^2-w^2),\qquad -2ru=fu-2v^2sw;$$

from which $$K=-k\frac{dX}{dx}=-k.C.\varepsilon^{rt+sx}.(s.\cos\overline{ut+wx+C'}-w.\sin\overline{ut+wx+C'}).$$

(342.) Let x' be the ordinate of any place upon the bank of the river, to which the situation of a particle of water corresponds at any instant. Then $x'=x+X$ nearly, or $x=x'-X$; and, as the only term of X which becomes large is $-bt$, we may take $x=x'+bt$. This makes $rt+sx=(r+bs)\,t+sx'$, $ut+wx=(u+bw)\,t+wx'$; and the expression for K corresponding to the place x' on the river bank is

$$K=-k.C.\varepsilon^{(r+bs)t+sx'}\left(s.\cos\overline{(u+bw)\,t+wx'+C'}-w.\sin\overline{(u+bw)\,t+wx'+C'}\right).$$

At the mouth of the river, $x'=0$, and this expression becomes

$$-kC.\varepsilon^{(r+bs)t}.\left(s.\cos\overline{(u+bw)\,t+C'}-w.\sin\overline{(u+bw)\,t+C'}\right).$$

But the law of the rise of the sea is assumed to be A. sin $\overline{nt+B}$. Making these expressions coincide, we have

$$r+bs=0, \qquad u+bw=n,$$

$$-kCs.\cos(C'-B)+kwC.\sin(C'-B)=0, \qquad kCs.\sin(C'-B)+kCw.\cos(C'-B)=A.$$

The two last equations give only the values of C and C′. Combining the two preceding them with the two found in (341.) we have four equations for the four quantities r, s, u, w; and eliminating r, u, w, we obtain

$$-(v^2-b^2)s^2+(v^2-b^2)\left(\frac{fn-2bns}{2(v^2-b^2)s+fb}\right)^2-fbs+\frac{2bfn^2-4b^2n^2s}{2(v^2-b^2)s+fb}-n^2=0;$$

a biquadratic equation for s. Then $w=\frac{fn-2bns}{2(v^2-b^2)\,s+fb}$. Without going through the solution, we will only remark, that when b is small, a solution may be obtained which will allow a negative value $-s'=\frac{-f}{2v-2b}$ to be taken for s; that then w has a negative value $-w'=\frac{-1}{v-b}$; and that the elevation of the water is then expressed by

$$A.\varepsilon^{-s'x'}.\sin\overline{nt-w'x'+B}.$$

This elevation is above the mean level of the river at that point. But the mean level there is higher than that of the sea by $x'.\sin\alpha$. Therefore the surface of the river is higher than the mean level of the sea by

$$x'\sin\alpha+A.\varepsilon^{-s'x'}.\sin\overline{nt-w'x'+B}.$$

Low water in the river may be higher than high water in the sea.

(343.) At low water at any place, $\sin\overline{nt-w'x+B}=-1$, and therefore the elevation of low water at any place, above the mean level of the sea, is $x'\sin\alpha-A.\varepsilon^{-s'x'}$. The elevation of the high tide of the sea above its mean level is $+A$. The low water then at a point up the river will be higher than the high water of the sea if $x'\sin\alpha-A\varepsilon^{-s'x'}$ be greater than A. As, by increasing x', $x'\sin\alpha$ may be made as great as we please, and $A\varepsilon^{-s'x'}$ as little as we please, it is evident that a point may be found where this condition is satisfied. The circumstance that low water on a tidal river may be higher than high water on the sea, paradoxical as it may appear, is therefore a simple consequence of theory.

(344.) We shall conclude with the following Problem. The water being in the state of undulation represented by $X=L.\cos\overline{it-mx}$, the forces which have maintained it in that state suddenly cease when $t=\alpha$: to find the subsequent motion of the water.

Motion of water supposing the tidal forces to cease.

(345.) It is evident that there can be no such multiplier as ε^{sx} in the expression for X, since there is none such when $t=\alpha$. Let therefore

$$X=\Sigma.C.\varepsilon^{rt}.\cos(ut+wx)+\Sigma.C'.\varepsilon^{rt}.\sin(ut+wx).$$

It is plain that w must $=\pm m$. This restricts the assumption to

$$X=C.\varepsilon^{rt}.\cos(ut+mx)+E.\varepsilon^{rt}.\cos(ut-mx)+C'.\varepsilon^{rt}.\sin(ut+mx)+E'.\varepsilon^{rt}.\sin(ut-mx).$$

We have first to find r and u. The general equations become $r^2-u^2=-fr-v^2m^2$; $-2ru=fu$. From the second, $r=-\frac{f}{2}$. Substituting in the first, $\frac{f^2}{4}-\frac{f^2}{2}+v^2m^2=u^2$, or $u=\sqrt{\left(v^2m^2-\frac{f^2}{4}\right)}$. Then the special conditions to be satisfied are, that, when $t=\alpha$, X must $=L.\cos it.\cos mx+L.\sin it.\sin mx$, and $\frac{dX}{dt}$ must $=-iL.\sin it.\cos mx+iL.\cos it.\sin mx$; or X must then $=L\cos i\alpha.\cos mx+L\sin i\alpha.\sin mx$, and $\frac{dX}{dt}$ must then $=-iL.\sin i\alpha.\cos mx+iL\cos i\alpha.\sin mx$. Comparing these with the quantities deduced from the assumed expression, we have

$$\varepsilon^{r\alpha}\cos u\alpha\,(C+E)+\varepsilon^{r\alpha}\sin u\alpha\,(C'+E')=L\cos i\alpha$$

$$\varepsilon^{r\alpha}\sin u\alpha\,(E-C)+\varepsilon^{r\alpha}\cos u\alpha\,(C'-E')=L\sin i\alpha$$

$$\varepsilon^{r\alpha}(r\cos u\alpha-u\sin u\alpha).(C+E)+\varepsilon^{r\alpha}(r\sin u\alpha+u\cos u\alpha).(C'+E')=-iL\sin i\alpha$$

$$\varepsilon^{r\alpha}(r\sin u\alpha+u\cos u\alpha).(E-C)+\varepsilon^{r\alpha}(r\cos u\alpha-u\sin u\alpha).(C'-E')=\quad iL\cos i\alpha.$$

From the first and third, C + E and C′ + E′ are found; from the second and fourth, E − C and C′ − E′ are found; and from these C, E, C′, E′, are found. Then the expression for X is

The motions will diminish rapidly.

$$\varepsilon^{-\frac{ft}{2}}.\left\{C.\cos\overline{ut+mx}+E.\cos\overline{ut-mx}+C'.\sin\overline{ut+mx}+E'.\sin\overline{ut-mx}\right\}.$$

The multiplier $\varepsilon^{-\frac{ft}{2}}$ shows that the oscillations will diminish rapidly and will therefore soon become insensible.

Tides and Waves.

(346.) The functions $\varepsilon^{\pm pt}.\overset{\sin}{\underset{\cos}{}}qx$, $\varepsilon^{rt}\overset{\sin}{\underset{\cos}{}}(ut\pm mx)$, $\varepsilon^{rt+sx}.\overset{\cos}{\underset{\sin}{}}(ut+wx)$, are in their meaning and application exactly analogous to the simpler expressions which we have used to represent the free tide-wave in (291.) and the articles which follow it.

Subsection 7.—Theory of Waves upon Open Seas.

Equations for water of three dimensions.

(347.) We shall now point out the form which the investigation assumes when the motion of water in space of three dimensions is considered.

Let z be the original horizontal co-ordinate of any particle measured at right angles to x, and Z the displacement of that particle in the direction of z at the time t, y being the vertical ordinate as before. Then, nearly as in (145.), we shall find the following equation of continuity:

$$\mathrm{Y}=\Xi\frac{d\eta}{dx}+\zeta\frac{d\eta}{dz}-\int_y\left(\frac{d\mathrm{X}}{dx}+\frac{d\mathrm{Z}}{dz}\right)(\text{from }\eta\text{ to }y),$$

where ζ is the value of Z corresponding to the bottom.

And, nearly as in (147.), we shall find the two following equations of equal pressure (no external force being supposed to act):

$$\frac{d^2\mathrm{X}}{dt^2}=\frac{d}{dx}\left\{-g\mathrm{K}+\int_y\frac{d^2\mathrm{Y}}{dt^2}\ (\text{from }k\text{ to }y)\right\},$$

$$\frac{d^2\mathrm{Z}}{dt^2}=\frac{d}{dz}\left\{-g\mathrm{K}+\int_y\frac{d^2\mathrm{Y}}{dt^2}\ (\text{from }k\text{ to }y)\right\}.$$

We shall not attempt to solve these equations, except in the case where the depth is uniform, and where the oscillations are of uniform period (as in all the preceding investigations). And, even with these limitations, we shall find our solution exceedingly restricted.

(348.) Assuming, then, the same function of y as that which has occurred in the preceding investigations, (the propriety of which will be proved by its satisfying the equation so as to make the solution possible as regards the other co-ordinates, with the utmost generality,) and assuming the same relation between m and n, and making our expressions multiply $\cos nt$. (the same investigation applying in all respects to $\sin nt$,) let us suppose

$$\mathrm{X}=\mathrm{U}.(\varepsilon^{my}+\varepsilon^{-my}).\cos nt,$$
$$\mathrm{Z}=\mathrm{V}.(\varepsilon^{my}+\varepsilon^{-my}).\cos nt,$$

U and V being functions of x and z only.

Then $$\mathrm{Y}=-\int_y\left(\frac{d\mathrm{U}}{dx}+\frac{d\mathrm{V}}{dz}\right).(\varepsilon^{my}+\varepsilon^{-my}).\cos nt=\frac{1}{m}.\left(\frac{d\mathrm{U}}{dx}+\frac{d\mathrm{V}}{dz}\right).(-\varepsilon^{my}+\varepsilon^{-my}).\cos nt.$$

And $$\frac{d^2\mathrm{Y}}{dt^2}=\frac{n^2}{m}.\left(\frac{d\mathrm{U}}{dx}+\frac{d\mathrm{V}}{dz}\right).(\varepsilon^{my}-\varepsilon^{-my}).\cos nt:$$

therefore $$-\int_y\frac{d^2\mathrm{Y}}{dt^2}(y\text{ to }k)=\frac{n^2}{m^2}\left(\frac{d\mathrm{U}}{dx}+\frac{d\mathrm{V}}{dz}\right).(-\varepsilon^{mk}-\varepsilon^{-mk}+\varepsilon^{my}+\varepsilon^{-my}).\cos nt.$$

Also $$-g\mathrm{K}=\frac{g}{m}\left(\frac{d\mathrm{U}}{dx}+\frac{d\mathrm{V}}{dz}\right)(\varepsilon^{mk}-\varepsilon^{-mk}).\cos nt.$$

Therefore $-g\mathrm{K}-\int_y\frac{d^2\mathrm{Y}}{dt^2}(y\text{ to }k)$, having regard to the equation $n^2(\varepsilon^{mk}+\varepsilon^{-mk})=gm(\varepsilon^{mk}-\varepsilon^{-mk})$, becomes

$$\frac{n^2}{m^2}\left(\frac{d\mathrm{U}}{dx}+\frac{d\mathrm{V}}{dz}\right)(\varepsilon\ \ +\varepsilon^{-my}).\cos nt.$$

Also $$\frac{d^2\mathrm{X}}{dt^2}=-n^2\mathrm{U}.(\varepsilon^{my}+\varepsilon^{-my}).\cos nt,\qquad\frac{d^2\mathrm{Z}}{dt^2}=-n^2\mathrm{V}.(\varepsilon^{my}+\varepsilon^{-my}).\cos nt.$$

Hence the equations of equal pressure become

$$-n^2\mathrm{U}.(\varepsilon^{my}+\varepsilon^{-my}).\cos nt=\frac{n^2}{m^2}.\frac{d}{dx}\left(\frac{d\mathrm{U}}{dx}+\frac{d\mathrm{V}}{dz}\right).(\varepsilon^{my}+\varepsilon^{-my}).\cos nt,$$

$$-n^2\mathrm{V}.(\varepsilon^{my}+\varepsilon^{-my}).\cos nt=\frac{n^2}{m^2}.\frac{d}{dz}\left(\frac{d\mathrm{U}}{dx}+\frac{d\mathrm{V}}{dz}\right)(\varepsilon^{my}+\varepsilon^{-my}).\cos nt,$$

or

$$m^2\mathrm{U}+\frac{d}{dx}\left(\frac{d\mathrm{U}}{dx}+\frac{d\mathrm{V}}{dz}\right)=0$$

$$m^2V+\frac{d}{dz}\left(\frac{dU}{dx}+\frac{dV}{dz}\right)=0;$$

equations which are of the most general kind for the determination of U and V, and which are cleared of y and t.

Partial differential equation whose solution is necessary.

(349.) If we differentiate the first of these equations with regard to x, and the second with regard to z, and then add them together, and if we put W for $\frac{dU}{dx}+\frac{dV}{dz}$, we find

$$m^2W+\frac{d^2W}{dx^2}+\frac{d^2W}{dz^2}=0.$$

It will be remarked that W is proportional to the factor of cos nt in the expression for K, so that, if we could solve this equation, we should at once obtain the expression for the elevation of the wave (supposed stationary) at every point. And as $m^2U=-\frac{dW}{dx}$, $m^2V=-\frac{dW}{dz}$, all the circumstances of the motion of the water would be completely known.

Form of solution which would be desirable.

(350.) There are, however, great difficulties in the solution of this equation. The most convenient form for our purposes would be $W=P\cos Q$, P and Q being functions of x and z. If we could obtain this, we could also obtain another $W'=P\sin Q$; and combining the former of these as factor with cos nt and the latter with sin nt, we should have for the value of K

$$-\frac{1}{m}(\varepsilon^{mk}-\varepsilon^{-mk})\,P\,(\cos Q\,.\,\cos nt+\sin Q\,.\,\sin nt)$$
$$=-\frac{1}{m}\,(\varepsilon^{mk}-\varepsilon^{-mk})\,.P.\cos\overline{nt-Q},$$

and the equation determining the position of the ridge of wave at any time t would be

$$Q=\text{constant}.$$

But the general solution of the equation in this form does not appear practicable.

(351.) There are two limited solutions (and perhaps others) which may be easily shown to satisfy the equation. The first may be interpreted partially; the second completely.

1st. Let $W=\phi(r)$, where $r=\sqrt{\{(x-a)^2+(z-b)^2\}}$. Then $\frac{dW}{dx}=\frac{dW}{dr}\,.\,\frac{dr}{dx}=\phi'(r)\,.\,\frac{x-a}{r}$: $\frac{d^2W}{dx^2}=\frac{\phi'(r)}{r}+\overline{x-a}\,.\left(\frac{\phi''(r)}{r}-\frac{\phi'(r)}{r^2}\right).\frac{dr}{dx}=\frac{\phi'(r)}{r}+\left(\phi''(r)-\frac{\phi'(r)}{r}\right)\frac{(x-a)^2}{r^2}$. Similarly $\frac{d^2W}{dz^2}=\frac{\phi'(r)}{r}+\left(\phi''(r)-\frac{\phi'(r)}{r}\right)\frac{(z-b)^2}{r^2}$. Substituting in the equation $m^2W+\frac{d^2W}{dx^2}+\frac{d^2W}{dz^2}=0$, we obtain

$$m^2\phi(r)+\frac{\phi'(r)}{r}+\phi''(r)=0.$$

Solution expressing annular waves.

The solution of this equation is the following, in which the letter S is put to denote the definite integral between the limits 0 and π:

$$\phi(r)=C.S_v\cos(mr\cos v)+C'.S_v\{\cos(mr\cos v).\log(r\sin^2 v)\}$$

where v is a new variable, introduced solely for the purpose of forming a function which is to be integrated, and disappearing entirely from the result, which is the sum of two integrals between definite limits. But the values of the two definite integrals cannot be expressed by means of any usually tabulated quantities, and must be computed numerically. (A table of the values of the first integral, to a small extent, will be found in the *Philosophical Magazine* for January, 1841, page 7.) Putting S′ and S″ for the two integrals, corresponding to a given value of r, the most general form for W or $\phi(r)$ will be

$$E'.S'.\cos(nt+F')+E''.S''.\sin(nt+F''),$$

E′, E″, F′, and F″, being arbitrary constants. It is evident that this form of W expresses a series of circular waves converging to or diverging from the point whose co-ordinates are a, b.

(352.) The equation determining W will also be satisfied by the sum of any number of functions $\phi_{,}(r_{,})$, $\phi_{,,}(r_{,,})$, &c., where $r_{,}=\sqrt{\{(x-a_{,})^2+(z-b_{,})^2\}}$, $r_{,,}=\sqrt{\{(x-a_{,,})^2+(z-b_{,,})^2\}}$, &c., and where each of the functions $\phi_{,}$, $\phi_{,,}$ &c. satisfies the equation $m^2\phi(r)+\frac{\phi'(r)}{r}+\phi''(r)=0$. That is, there may be any number of systems of such circular waves, each system converging to or diverging from an arbitrary centre.

Solution expressing parallel waves.

(353.) 2d. Let $W=A.\cos(ax+bz)$: on substituting we obtain $m^2-a^2-b^2=0$ as the only condition. The same holds if we assume $W'=A.\sin(ax+bz)$: combining the former as factor with cos nt and the latter with sin nt, we find for the elevation of any part of the water

$$-\frac{1}{m}(\varepsilon^{mk}-\varepsilon^{-mk})\,\mathrm{A}.\cos(nt-ax-bz).$$

The positions of the ridges of waves at the time t are determined by making $ax+bz=nt\pm\pi$, or $=nt\pm3\pi$, or $=nt\pm5\pi$, &c. The ridges, therefore, are all parallel to the line whose equation is $ax+bz=0$. If from the origin of co-ordinates we draw a perpendicular upon one of the ridges, its length is found to be $\frac{nt\pm\pi}{\sqrt{a^2+b^2}}$, or $\frac{nt\pm3\pi}{\sqrt{a^2+b^2}}$, &c., that is $\frac{nt\pm\pi}{m}$, $\frac{nt\pm3\pi}{m}$, &c. The distance, therefore, from one ridge to the next is $\frac{2\pi}{m}$: and the velocity with which each ridge travels on is $\frac{n}{m}$.

(354.) The equation determining W will also be satisfied by the sum of any number of expressions $\mathrm{A}_{,}\cos(nt-a_{,}x-b_{,}z)$, $\mathrm{A}_{,,}\cos(nt-a_{,,}x-b_{,,}z)$, &c., provided that $a_{,}^2+b_{,}^2=m^2$: $a_{,,}^2+b_{,,}^2=m^2$, &c. Each of these denotes a series of parallel waves with the interval $\frac{2\pi}{n}$ between one wave and the next, the waves being parallel to any arbitrary line. And the circumstance of the equation being satisfied by the algebraic sum of the different solutions indicates that the elevation of the water at the intersection of any ridges will be the algebraic sum of the elevations corresponding to each ridge. The same remark applies to the sum of the solutions representing circular waves, or to the sum of any number of solutions of both these kinds or of any other kinds.

Reflexion of parallel waves from a straight boundary.

(355.) Now suppose the water to be terminated on one side by a straight boundary: let the co-ordinates be so taken that the boundary may be parallel to z; let the corresponding value of x be c; then, whatever be the value of z while $x=c$, the motion of the particles of water in the direction of x must at all times be 0. For, all the particles which are once in contact with the boundary, that is, all those for which $x=c$, must remain in contact with the boundary; that is, they must always have $x=c$; and, therefore, X must $=0$. It is plain that this condition cannot be satisfied if we confine the expression for the elevation to the single term $-\frac{1}{m}(\varepsilon^{mk}-\varepsilon^{-mk})\,\mathrm{A}.\cos(nt-ax-bz)$. For then $\mathrm{W}=\mathrm{A}.\cos(ax+bz)$, $\mathrm{W}'=\mathrm{A}.\sin(ax+bz)$: $\mathrm{U}=-\frac{1}{m^2}.\frac{d\mathrm{W}}{dx}$ $=\frac{a}{m^2}\mathrm{A}.\sin(ax+bz)$, $\mathrm{U}'=\frac{-a}{m^2}\mathrm{A}.\cos(ax+bz)$; and the complete value of $\mathrm{X}=\mathrm{U}.\cos nt+\mathrm{U}'.\sin nt=$ $-\frac{a\mathrm{A}}{m^2}\sin(nt-ax-bz)$; which is not generally $=0$ when $x=c$. But it may be made to satisfy the required condition by adding another term which itself satisfies the original equation $m^2\mathrm{W}+\frac{d^2\mathrm{W}}{dx^2}+\frac{d^2\mathrm{W}}{dz^2}=0$. For let the values, as increased by the new terms, be

$$\mathrm{W}=\mathrm{A}\cos(ax+bz)+\mathrm{A}\cos(2ac-ax+bz),$$
$$\mathrm{W}'=\mathrm{A}\sin(ax+bz)+\mathrm{A}\sin(2ac-ax+bz);$$

then the new value of U or $-\frac{1}{m^2}\frac{d\mathrm{W}}{dx}$ is

$$\frac{a\mathrm{A}}{m^2}\sin(ax+bz)-\frac{a\mathrm{A}}{m^2}\sin(2ac-ax+bz);$$

and that of U′ is

$$-\frac{a\mathrm{A}}{m^2}\cos(ax+bz)+\frac{a\mathrm{A}}{m^2}\cos(2ac-ax+bz):$$

and, therefore, the new value of X or $\mathrm{U}.\cos nt+\mathrm{U}'.\sin nt$ is

$$-\frac{a\mathrm{A}}{m^2}\sin(nt-ax-bz)+\frac{a\mathrm{A}}{m^2}\sin(nt-2ac+ax-bz);$$

and upon making $x=c$ this expression becomes

$$-\frac{a\mathrm{A}}{m^2}\sin(nt-ac-bz)+\frac{a\mathrm{A}}{m^2}\sin(nt-ac-bz)$$

which $=0$ whatever be the values of x and t. Thus we find that the existence of one series of waves and the assumption of a rectilinear boundary imply the existence of another system of waves, whose elevation will be represented by substituting in the expression for K the additional terms of W and W′, and will therefore be

$$-\frac{1}{m}(\varepsilon^{mk}-\varepsilon^{-mk}).\mathrm{A}\,\{\cos(2ac-ax+bz)\cos nt+\sin(2ac-ax+bz).\sin nt\}$$
$$=-\frac{1}{m}(\varepsilon^{mk}-\varepsilon^{-mk}).\mathrm{A}.\cos(nt-2ac+ax-bz).$$

This expression, examined in the same manner as before, represents a series of parallel waves, in which the equation to the ridge of every one is $-ax+bz=nt-2ac\pm\pi$, &c., and which are all parallel to the line whose equation is $-ax+bz=0$. The ridges of the former waves were found to be parallel to the line whose equation is $ax+bz=0$. Hence the inclinations of the ridges of the two sets of waves to the boundary are equal, but they are inclined opposite ways. This is the mathematical explanation of the reflexion of waves from a straight boundary.

(356.) The whole elevation of the waves is

$$-\frac{1}{m}(\varepsilon^{mk}-\varepsilon^{-mk})\,\mathrm{A}\,(\cos\overline{nt-ax-bz}+\cos\overline{nt-2ac+ax-bz});$$

which, when $x=c$, becomes

$$-\frac{2}{m}(\varepsilon^{mk}-\varepsilon^{-mk})\,\mathrm{A}.\cos\overline{nt-ac-bz}.$$

The coefficient, therefore, for the undulation at contact with the boundary, is twice as great as that of an unreflected wave.

Reflexion of waves of any kind from a straight boundary.

(357.) In the same manner, if we take the expression for W in its most general state, putting it in the form $\phi(x,z)$, we may add to it another term $\phi(\overline{2c-x},z)$, which will satisfy the equation $m^2\mathrm{W}+\frac{d^2\mathrm{W}}{dx^2}+\frac{d^2\mathrm{W}}{dz^2}=0$ equally well, and which in the expression for X adds the new term $+\phi'(\overline{2c-x},z)$ to the former term $-\phi'(x,z)$, the sum of which is 0 when $x=c$. And, as above, the expression for K is

$$-\frac{1}{m}(\varepsilon^{mk}-\varepsilon^{-mk})\{\phi(x,z)+\phi(\overline{2c-x},z)\},$$

which, when $x=c$, becomes $-\frac{2}{m}(\varepsilon^{mk}-\varepsilon^{-mk}).\phi(c,z)$, or is double that at the same point in an unreflected wave. The additional term for W being $\phi(c+\overline{c-x},z)$, and the original term being $\phi(c+\overline{x-c},z)$, it is evident that the system of waves represented by one expression depends on $x-c$, in the same manner in which the other depends on $c-x$, and is, therefore, a reflected system whose form is exactly similar to the form in which the original system would have proceeded if not stopped by the boundary.

(358.) Leaving for the present the consideration of the motion of the waves as determined by the differential equations, we shall consider one case in which we seem to derive some assistance from general reasoning.

Form of the crest of the wave in broad channels which are shallow near the sides.

(359.) Suppose that a tide-wave is travelling along a canal of large dimensions, and of variable depth in its cross section, the depth diminishing gradually to both shores. (We may suppose the dimensions to be such as those of the English Channel, or any similar arm of the sea.) It is evident that the investigation of (218.) does not apply here: for, on account of the shallowness of the water at the sides, the velocity of flow towards both sides to produce the elevation of water there must be comparable with, perhaps equal to, the velocity of flow at mid-channel in the direction of the canal's length. Moreover, as the slope of the bottom is exceedingly small, the waves in every part of the channel will be travelling in nearly the same manner as if the extent of sea of the same depth were infinitely great, and will therefore travel with the velocity due to that depth: and, therefore, the ridge of wave cannot possibly stretch transversely to the channel, and travel along with uniform velocity lengthways of the channel. The state of things, then, will be this: the central part of the wave will advance rapidly (171.) along the middle of the channel; the lateral parts will not advance so rapidly; and the whole ridge will assume a curved shape, its convex side preceding. When this form is once acquired, it may perhaps proceed with little alteration; for if, as in figure 18, we suppose two such curves exactly similar, but one a little in advance of the other, the space which separates the wings of the two curves, measured perpendicularly to the curves, (the direction in which that part of the wave must really travel,) is much less than the space which separates the centres of the curves, and by proper inclination may be less in any proportion; and, therefore, may represent exactly the space travelled over by the wave at that depth while the wave at the greater depth travels over the greater space. That part of the ridge of the wave which is nearest to the coast will, therefore, assume a position nearly parallel to the line of coast.

(360.) Now the wave whose ridge is nearly parallel to the coast, or which advances almost directly towards the coast, will be a wave of the same character as that treated of in (307.). For the slope of the beach adds to the surface of the sea a very insignificant quantity, as compared with the breadth of the tide-wave, and the general effect is the same as if a perpendicular cliff terminated the sea on that side. Therefore, for those parts of the sea which are near to the coasts the law of (307.) holds; namely, the greatest horizontal displacement of the particles occurs at the same time as the greatest vertical displacement; and, therefore, when the sea is rising, the water is, for some distance from the coast, flowing towards the coast, and when it is falling, the water is flowing from the coast.

(361.) In mid-channel, the motion of the water will be such as is described in (184.), &c.; that is, the water will be flowing most rapidly up the channel at the time of high water, and its motion upwards will cease when the water has dropped to its mean height.

(362.) From this there follows a curious consequence with regard to the currents at an intermediate distance from the shore, where the effects of these two motions may be conceived to be combined.

At high water the water is not flowing to or from the shore, but is flowing up the channel.

When the water has dropped to its mean elevation, the water is ebbing from the shore, but is stationary with regard to motion up or down the channel.

At low water, the water is not flowing to or from the shore, but is running down the channel.

When the water has risen to its mean height, the water is flowing to the shore, but is stationary with regard to motion up or down the channel.

Revolving motion of the tide near the shore.

(363.) Consequently, in the course of one complete tide, the direction of the current will have changed through 360°, the water never having been stationary. And the direction of the change of current will be of such a kind that, if we suppose ourselves sailing up the mid-channel, the tide-current will turn, in those parts which are on the *left* hand, in the *same* direction as the hands of a watch; and in those parts which are on the *right* hand, in the direction *opposite* to that of the hands of a watch.

(364.) Beyond this we can add little to the Theory of Waves upon a sea extended in both dimensions. But the following remarks will be found important with reference to the method of determining from observations some of the phenomena of tides.

Cotidal lines on open seas.

(365.) In tracing the progress of the tide across an extended sea, we cannot observe the different waves as we can those upon a small piece of water. We can do nothing but make observations of the time of the rise and fall of the sea at many different points along the shores of the bounding continents, or at islands in different parts of the sea: and when we have thus ascertained the absolute time of high water at many different points, if they are sufficiently numerous, we may draw lines over the surface of the sea passing through all the points at which high water takes place at the same absolute instant. These lines (adopting the word introduced into general use by the highest authority on the discussion of tide-observations) we shall call *cotidal lines*. The tracing out the cotidal lines in different seas is the greatest advance that has yet been made in the discussion of the phenomena of the tides in open seas.

The relation between the cotidal lines and the waves from which they originate is very obscure.

(366.) Now when the series of waves is single, the cotidal lines correspond exactly with the lines marking the position of the ridge of the wave at different times. But when the series of waves is compound, it may happen that the form of the cotidal lines will not present to the eye the smallest analogy with the forms of the ridges of the mingled waves. This will be seen in a simple instance.

(367.) Suppose that there are two systems of parallel waves rolling across the sea at the same time, the ridges of all the waves of one series being parallel to x, and the ridges of all the waves of the other being parallel to z. The forms of the ridges, as they might be seen by an eye placed at a sufficient distance, would be the intersecting lines represented in figure 19. The elevation of water caused by the former at the time t will be represented by $b.\cos\overline{nt-mz}$: that caused by the latter will be represented by $a.\cos\overline{nt-px}$. We have taken the same coefficient for t in both these expressions, because the recurrence of tide-waves, whether forced waves, or free waves introduced in the integration for satisfying the limiting conditions, must be periodical as the exciting cause. But the coefficients of x and z may be different: thus, for instance, one of these waves may be a forced tide-wave, and the other may be a free tide-wave, in which case the coefficients (292.) will not necessarily be the same: this is, however, immaterial to the present investigation.

(368.) The whole elevation, then, of the water at any point will be

$$a.\cos\overline{nt-px}+b.\cos\overline{nt-mz}$$

$$=(a\cos px+b\cos mz)\cos nt+(a\sin px+b\sin mz)\sin nt,$$

which has its maximum value for that point when

$$\tan nt=\frac{a\sin px+b\sin mz}{a\cos px+b\cos mz}.$$

This expression for t determines the time of high water at that place; and, therefore, the line connecting all the points at which it is high water at the same instant will be determined by making $\frac{a\sin px+b\sin mz}{a\cos px+b\cos mz}$ equal to the same quantity $\tan nt$. Giving a definite value C to the quantity nt, we have for the equation to a certain cotidal line,

$$\frac{a\sin px+b\sin mz}{a\cos px+b\cos mz}=\tan \mathrm{C},$$

from which

$$\sin\overline{mz-\mathrm{C}}=-\frac{a}{b}\sin\overline{px-\mathrm{C}}.$$

(369.) If $a=b$, this equation becomes $\sin\overline{mz-\mathrm{C}}=-\sin\overline{px-\mathrm{C}}$; whence $mz-\mathrm{C}=-px+\mathrm{C}$, or $=-px+\mathrm{C}\pm 2\pi$, or $=-px+\mathrm{C}\pm 4\pi$, &c., or $mz-\mathrm{C}=px-\mathrm{C}\pm\pi$, or $=px-\mathrm{C}\pm 3\pi$, &c. These expressions evidently represent two series of straight lines, making equal angles with the co-ordinates: one of them is stationary, (as C or nt disappears from the equation,) and its deduction from the investigation above denotes that there is no sensible tide along those lines: the other is the real system of cotidal lines. The former is represented in figure 20 by the double lines, the latter by the single lines. In drawing the latter, we have supposed C to vary successively by $\frac{\pi}{2}$ at each step.

(370.) If $a<b$, the first expression for $mz-\mathrm{C}$ is included between the arc whose sine is $\frac{a}{b}$, and the arc

whose sine is $-\frac{a}{b}$, which values $mx - C$ attains when $px - C$ is $\frac{\pi}{2} \pm 2n\pi$ and $-\frac{\pi}{2} \pm 2n\pi$. The corresponding curves for values of C varying successively by $\frac{\pi}{2}$ are represented in figure 21.

(371.) If $a > b$, the curves will be such as those represented in figure 22.

(372.) It is evident that the contemplation of these curves (more especially if a small part only of each can be traced) will not easily enable us to discover the nature of the simple interfering systems of waves from which they originate. If either system were complicated, as in (308.), the difficulty would be still greater.

SECTION V.—ACCOUNT OF EXPERIMENTS ON WAVES.

(373.) Our theory of waves, as we have remarked in the Introduction, is not the most complete that could be devised. It embraces (as we believe) every case of general interest to which mathematics are at present applicable, but it does not comprehend those special cases which have been treated at so great length by Poisson (*Mémoires de l'Institut*) and Cauchy (*Savans Etrangers*). With respect to these we may express here an opinion, borrowed from other writers, but in which we join, that as regards their physical results these elaborate treatises are entirely uninteresting; although they rank among the leading works of the present century in regard to the improvement of pure mathematics. We shall not therefore trouble ourselves with detailing the few imperfect experiments of Biot (*Mémoires de l'Institut*) and Bidone (*Turin Memoirs*) which have been made in verification of these theories.

(374.) One of the most important works that has been published, in regard to experiments as well as to the theory of Waves, is that by the two brothers Weber, entitled "*Wellenlehre auf Experimente gegründet.*" This work contains an abstract of all the theories and all the principal experiments of preceding writers that the authors had been able to collect. The points however to which we shall allude here are the experiments made by the Webers themselves. These were made with an apparatus which they call *Wellenrinne*. It is a very narrow trough with glass sides. In one instance it was 5 ft. 4 in. long, (Paris measure,) about 8 inches deep, and about ½ an inch wide; in another instance it was 6 feet long, 2½ feet deep, and a little more than an inch wide. The glass sides were properly supported by pieces of wood connected with the bottom; in the smaller, the glass sides were continuous; in the larger, the glass only occupied 6 openings in different parts of the sides, the other parts being of wood. Some experiments were made with quicksilver, and some with brandy; but the principal part were made with water containing a great number of floating particles of the same specific gravity as the water; by observing the movements of these through the glass sides, sometimes with the naked eye and sometimes with a microscope, the motions of the particles of water, even to the bottom, were easily examined. The waves of experiment were generated by plunging a glass tube into the fluid, raising the fluid into the tube by suction, and then allowing it suddenly to drop.

Weber's *Wellenrinne*.

Motion of particles floating in the water observed.

Method of determining the form of the wave.

(375.) The form of the wave was determined by immerging into the liquid with its plane vertical a slate sprinkled with flour, and suddenly withdrawing it. In this way it appears that a satisfactory trace of the front of the wave was obtained; the liquid removing the flour from every part which it touched. In a nearly similar manner the form of the back of the wave was obtained; the slate being in this case suddenly plunged into the fluid; these determinations are however confessedly much less satisfactory than the former. The experimenters, however, were able to ascertain that, when the height of the wave was large in proportion to its depth, its front was much steeper than its back, as our theory of (203.) gives it.

(376.) The wave was sometimes observed when it had run to one end of the trough and was reflected there, (a method carried to great perfection in Mr. Russell's experiments, to be described hereafter.) But generally the observations were made soon after the wave was formed. We have no doubt that some irregularities in the results were entirely due to the mixture of waves of various lengths which always occurs at first, and that they would have been avoided if the actual observation had been deferred till the principal wave had cleared itself of the small waves.

(377.) By inspection of the motion of the particles, the Webers discovered the following general rules. When a wave-ridge is followed by an equal wave-hollow, every particle moves in an ellipse, (or a curve as near to an ellipse as the eye can judge,) whose major axis is horizontal; the motion of the particle when in the highest part of the ellipse being in the same direction as the motion of the wave, and in the opposite direction when at the lowest part of the ellipse. (Fig. 23 is copied from Weber's figure.) When a small wave-hollow follows a large wave-ridge, the motion is such as is represented in fig. 24; and when a large wave-hollow follows a small wave-ridge, the motion is such as is represented in fig. 25. These motions are all in general conformity with the results of our theory in (182.); it being remarked that, by the theory of (226.), &c., the same may (with certain combinations) apply to a single wave. At different depths the motion was different; the horizontal motion being diminished in some degree for the deeper particles, and the vertical motion being very much diminished, so that, on approaching the bottom, the ellipse became nearly a horizontal line, as shown in figure 26. These results agree with those of (177.), &c. It was also found that different particles in the same vertical line described corresponding parts of their courses at the same instant of time, as we have found in (162.).

(378.) From contemplation of these experimental circumstances, the Webers constructed figure 27 to represent the motion of particles at the surface of a progressive wave followed by other waves. We need scarcely point out to the reader that these motions coincide exactly with those which we have found in (182.).

(379.) Some discordances were found in the results, depending on the manner in which the wave was produced, and which it would be extremely difficult to compare with theory. Thus when the suction-tube was plunged deep in the fluid, it was sometimes found that the horizontal motion of particles near the bottom was greater than that of particles at about half the depth. The form of the waves was varied by plunging the suction-tube to different depths. When it was very deep, the wave produced was long and flat; when it only touched the surface, the wave was short and high. In the latter case it was found that each particle performed its elliptical revolution in a shorter time than in the former; as the theory of (169.) gives.

(380.) In some experiments it was found that the time occupied by particles near the bottom in describing their elliptic courses was less than that occupied by particles near the surface. It is plain that some complicated system of waves was here produced by some peculiarity in the primary disturbance, of which we can give no further account.

(381.) Each particle described its second course in a shorter time than the first. This is evidently caused by a small wave following a large one.

(382.) In regard to the general velocity of the wave, the Webers found that it was increased by increasing the depth of the fluid in the trough, but they did not ascertain the law. They also found that it was independent of the specific gravity of the fluid. They found that a bulky wave travels more quickly than a small one, as appears from (208.).

(383.) Observations were also made of the motion of the particles when two equal waves meet each other. It was found here that the motion of each particle was backwards and forwards in a straight line, as is represented in fig. 28, which is copied from Weber's figure. We need scarcely to point out that this is precisely the same kind of motion as that which we have found from theory in (189.), &c.

(384.) Other observations were made by the Webers, but none which seem to bear closely upon our theory.

(385.) In regard to the experiments that we have abstracted, we may give our opinion as follows:—The contrivance of using a vessel with glass sides and observing the motions of floating particles is one so admirably adapted to overcome the greatest of all the difficulties attending the comparison of a wave-theory with experiment, namely, that of ascertaining the laws of movement of individual particles, that we think it gives these experiments a claim for superiority above all others. In other respects we think causes of uncertainty may be pointed out. The narrowness of the troughs used makes the effect of any irregularity of the sides great. The rapidity of the observation throws great doubt on the measures of time. However much the Webers might be inclined to trust to their "Tertien-Uhr," (a watch with which the $\frac{1}{60}$ part of a second of time could be observed,) we have little confidence in the use of it. The same cause—namely, the observation of the waves as soon as they were formed—has introduced great complexity into the facts of experiment, which would not have existed if the slower process used by Mr. Russell had been adopted. Although a *complete* theory ought to explain the *most complicated* experiments, yet, under all the difficulties of wave-mathematics, we must confine ourselves to simple cases if we wish to have valid comparisons of theory and observation. We would however point out to any future observer the use of Weber's *Wellenrinne* with several of Russell's methods of observation as likely to give better results than any yet obtained.

(386.) No allusion is made to theory, in the course of the Webers' experiments; and though they have stated the leading points of several theories, (in another part of their book,) they do not appear to have the power of familiarly applying them. We look upon their experiments therefore as quite free from theory, and for that reason we consider their coincidences with theory as peculiarly valuable.

Russell's experiments.

(387.) Mr. Russell's experiments on Waves are contained in the Report of the Seventh Meeting of the British Association, p. 417—496. They constitute, upon the whole, the most important body of experimental information in regard to the motion of Waves which we possess. We shall endeavour here to epitomize the principal contents of that paper, (omitting, for the present, all that relates to the tide-wave;) it will be necessary, however, to make some remarks upon Mr. Russell's references to theory, because we believe that any one who should derive his first knowledge of the nature of waves from that paper would receive from it a most erroneous notion of the extent of the Theory of Waves at the date of those experiments.

Apparatus for creating a wave.

(388.) We shall commence with the experiments made with apparatus arranged expressly for this purpose. A rectangular trough or cistern was constructed, 20 feet long, 1 foot broad, and more than 7 inches deep. At one end, an additional length of 7·3 inches was left, so that in fact the trough really was an uninterrupted trough, whose length was 20 feet 7·3 inches. Only 20 feet, however, was used in the experiments, the remaining part being used for the generation of a wave, in one of the following manners. A sluice being placed at the distance 7·3 inches from the end, water was poured into the small part of the trough behind the sluice, to a known height above the surface of the water in the trough; then, upon raising the sluice, that portion of this water which was higher than the general level (and whose volume therefore was known) rushed into the trough, forming a swell there which was immediately propagated as a wave along the surface of the water in the trough; and the sluice, being depressed, formed a smooth end to the trough in that part from which the wave began. Or, a vertical rectangular trunk, occupying the whole or a part of the small portion at the end of the horizontal trough was filled with water to a certain height, and, by lifting the trunk, that water was allowed to gush out below its lower edge. Or, the sluice of which we have spoken was used to form a wave by merely agitating it with the hand. And in some experiments the disturbance was given by pressing a solid into the water, and in others by withdrawing a solid from the water.

Mode of increasing the range of a wave.

(389.) The method used for measuring the velocities of the waves is extremely ingenious. The length of 20 feet was far too small to permit of any accurate determination of velocity. But Mr. Russell remarked that the wave, upon meeting one of the vertical ends of the trough, was reflected without alteration of form, and therefore could be observed in its reflected course as well as if the trough had been prolonged; and, as the same remark applied to every reflection at each end of the trough, the trough might be used as a channel of indefinite length. (The theory of (355.) and (357.) shows that the reflection from the plane end will in all cases produce a wave of exactly the same kind as that which comes in contact with the end, whatever that kind may be.) Thus the wave was sometimes observed after it had been reflected 60 times, or after it had really described a length of 1200 feet. Moreover, the progress of the wave was observed without difficulty at a great number of points in its course,—for instance, in the experiment just cited, at three points in each length of 20 feet, or in 180 points in the length of 1200 feet. The first observations were usually made after the wave had run the length of the trough once or twice; this allowed many small waves (such as apparently have injured Weber's experiments) to separate themselves and disappear.

Mode of observing the passage of a wave.

(390.) The method of observing the time at which the crest of a wave passed a given point was most happy. The flame of a candle, placed above the trough and at a small horizontal distance from it, was reflected by a mirror in an inclined position downwards to the water, then by the surface of the water it was reflected upwards, and being received upon another inclined mirror was reflected to the eye of an observer, who viewed it through an eye-tube, furnished with an internal wire and a more distant mark for directing the observer's eye. When the water was at rest, or when the horizontal surface at the top of the wave was passing under the mirror, the candle was seen in the centre of the eye-tube; when an inclined part of the wave (either the anterior or the posterior) was passing, the candle was seen on one or other side of the eye-tube. In this manner the passage of the highest part of a wave whose length was three feet, and whose height was only one-tenth of an inch, could be observed with accuracy.

Mode of observing the length and height of a wave.

(391.) The length of the wave was observed by adjusting two fine conical points, which nearly touched the quiescent surface, so that the anterior part of the wave would touch one and the posterior part would leave the other at the same instant. The height of the wave was observed by noting the elevation of the water in small pipes passing from the side of the trough and turning upwards at its outside. We doubt the accuracy of these determinations; they are, however, less important than the determination of velocity; yet we shall presently find that fuller information regarding them would have been valuable.

Species of wave observed by Russell.

(392.) Mr. Russell's researches, in these experiments, were directed entirely to the examination of what he denominates "The great primary wave," and which he describes as "differing in its origin, its phænomena, and its laws, from the undulatory and oscillatory waves which alone had been investigated previous to the researches of Mr. Russell." We are not disposed to recognize this wave as deserving the epithets "great" or "primary," (the wave being the solitary wave whose theory is discussed in (226.) &c.,) and we conceive that, ever since it was known that the theory of shallow waves of great length was contained in the equation $\frac{d^2X}{dt^2} = gk\frac{d^2X}{dx^2}$ (195.), with limitations similar to those in (226.), the theory of the solitary wave has been perfectly well known. Leaving this, however, we may state that Mr. Russell's experiments were all made upon a single wave of considerable length, similar to that discussed in (230.) and (232.), in which a particle is actually moved a certain distance by the wave and then remains at rest in a position differing from its original position. The result in (234.) shows that such a wave may travel, without any force to maintain its motion, provided it be long in proportion to the depth of the fluid; and provided that its velocity be $\sqrt{gk}$, k being the depth; or in other words, that it can, when moving freely, have no other velocity than $\sqrt{gk}$. We are not able to state fully how far Mr. Russell's experiments satisfy the former condition: for Mr. Russell was not aware of the influence of the length of the wave in any case, and therefore has not given it here. Supposing, however, (as his incidental remarks imply,) that the length was 3 feet, this length may correspond to a in the second or principal term in the expression of (232.), and as a has the same place there which λ has in (165.), &c., we may consider $\lambda = 3$ feet. Therefore, when the depth was 6 inches, $\frac{\lambda}{k} = 6$; when the depth was 4 inches, $\frac{\lambda}{k} = 9$, &c. The velocity is therefore (see the table in (170.)) sensibly not the same as if the wave were infinitely long. The wave, therefore, (in conformity with the remarks in (235.),) would tend to split into several waves, each of which would move with its own velocity; and this appears to have happened in some instances (rejected in Mr. Russell's table of results). But the difference of velocities would be small, and probably the elevation observed would be that of the first part, which corresponds to $\lambda = 3$ feet.

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(393.) There is, however, another point to be considered, namely, that the height of the wave, in many of the experiments, bears a sensible proportion to the depth. According to the theory of (208.), supposing the succession of waves continuous, the top of the wave would travel with a velocity greater than that due to the undisturbed depth, and even greater than that due to the disturbed depth, and expressed by $\sqrt{gk} \times (1+3b)$, where $b = \frac{\text{height of wave}}{\text{depth of water}}$. But if, as in continuous waves, we refer our first calculation not to the undisturbed depth but to the mean depth; then instead of k we must put $k\left(1+\frac{b}{2}\right)$, the mean depth; and instead of $3bk$ we must put $\frac{3bk}{2}$, the greatest elevation above the mean being $\frac{bk}{2}$. Thus the last formula becomes

$$\sqrt{gk\left(1+\frac{b}{2}\right)\left(1+\frac{3b}{2}\right)} = \sqrt{gk}(1+2b).$$

(394.) To examine, then, the general coincidence of Mr. Russell's results with the theory, we have proceeded thus:—We have taken the abstract in pp. 440, 441, 442, of the *Report of the British Association*, having corrected a few errors in it, and have divided the experiments into groups in which the depth of the water and the height of the wave are nearly equal. We have assumed that the mean of the observed velocities corresponds to the mean of the depths, &c., an assumption which is not rigorously true, but probably much nearer to truth than any one experiment. We have then computed the theoretical velocity for the undisturbed depth by the formula of (169.), &c., supposing $\lambda = 36$ inches; and in other columns we have altered this velocity in the proportion of $1 : \sqrt{1+b}$, $1 : \sqrt{1+3b}$, and $1 : \sqrt{1+2b}$.

Experiments in which the Height of the Wave is small.

Limits of Groups in the "Total Depth" of Mr. Russell's Table.	Undisturbed depth of Water in inches.	Height of Wave in inches.	Observed velocity in feet per Second.	Velocity computed for undisturbed Depth.	Computed Velocity $\times\sqrt{1+b}$.	Computed Velocity $\times\sqrt{1+3b}$.	Computed Velocity $\times\sqrt{1+2b}$.
1·05 and 1·10	1·000	0·075	1·670	1·629	1·689	1·803	1·747
1·30	1·150	·150	1·810	1·744	1·854	2·057	1·958
3·09 to 3·23	2·963	·207	2·860	2·702	2·795	2·972	2·885
3·32 and 3·40	3·080	·280	2·960	2·747	2·869	3·099	2·986
4·00 to 4·31	3·903	·256	3·310	3·016	3·114	3·300	3·208
5·20 to 5·50 (excluding 5·21)	5·088	·252	3·758	3·303	3·384	3·540	3·463
6·40 to 6·65	6·220	·304	4·094	3·495	3·579	3·742	3·662
7·42 to 7·70	7·040	·474	4·406	3·597	3·716	3·943	3·831
Experiments in which the Height of the Wave is large.							
1·20	1·000	0·200	1·760	1·629	1·785	2·061	1·928
1·62	1·300	·320	2·060	1·858	2·072	2·446	2·267
2·19	1·900	·290	2·300	2·217	2·380	2·677	2·533
3·35 to 3·41	2·960	·420	3·010	2·701	2·887	3·225	3·061
3·50 to 3·61	3·020	·532	3·080	2·724	2·954	3·368	3·168
3·69 to 3·97	3·007	·830	3·252	2·719	3·072	3·677	3·388
4·40 to 4·75	3·910	0·625	3·505	3·018	3·250	3·671	3·467
5·21	3·870	1·340	3·820	3·007	3·488	4·293	3·911
5·61 to 5·82	5·070	0·692	3·970	3·300	3 518	3·917	3·723
6·15 to 6·40	5·080	1·160	4·170	3·302	3·659	4·286	3·985
6·69 to 7·20	6·034	0·823	4·262	3·468	3·697	4·117	3·912
7·74 to 8·00	6·946	0·884	4·497	3·586	3·808	4·216	4·017

(395.) The experiments which are most favourable for determining the influence of the height of the wave are those of the second group. If we compare the column of "Velocity computed for undisturbed depth" with the column "Observed velocities," we find that *all* the computed velocities are too small. If we compare the "Computed velocity $\times\sqrt{1+b}$," which is the same as that due to the depth measured from the crest of the wave to the bottom of the trough, we find that 9 are too small and 3 too great. If we compare the "Computed velocity $\times\sqrt{1+2b}$," which is that deduced from our theory of (208.), we find that 5 are too small and 7 too great. If we compare the "Computed velocity $\times\sqrt{1+3b}$," we find that 3 are too small and 9 too great. The comparison of the first group leads to nearly the same result; the numbers in the corresponding columns being — all too small — 6 too small, 2 too great — 4 too small, 4 too great — 4 too small, 4 too great. On the whole, therefore, we think ourselves fully entitled to conclude from these experiments that the theory of (208.) is entirely supported; and that the velocity is correctly calculated by supposing it to be that due to the mean depth increased by three times the semi-oscillation in depth, or the whole depth from the crest of the wave increased by the whole oscillation in depth.

(396.) The reader will, however, remark that the *excesses* of our computed quantities are for the most part in the *small* depths of water, and the *defects* in the *great* depths. We think it most likely that this is due to the difference in the lengths of the waves. It is not unlikely that λ was less than 36 inches in the small depths, and greater than 36 inches in the great depths. If we had calculated with such numbers, we should have found smaller computed velocities for the small depths, and greater for the great depths; and the agreement with the observed velocities would have been extremely close.

the length of the waves.

Experiments of a general character.

(397.) Other experiments of Mr. Russell's were directed to the inquiry, whether the mode of producing the wave (in other words, the form of the wave) influenced its velocity; it was found that no difference of velocity was perceptible with waves produced in different ways. This is in accordance with (234.). Experiments were also made, (of which no details are given,) which showed that the motion of the particles from the surface to the bottom of the channel is the same, and that particles once in a vertical plane continue in a vertical plane. These results agree with those of (180.).

Negative wave produced by the paddles of a steam-boat.

(398.) Some experiments were made by Mr. Russell on what he calls a *negative* wave—that is, a wave which is in reality a progressive hollow or depression. But (we know not why) he appears not to have been satisfied with these experiments, and has omitted them in his abstract. All the theories of our IVth Section, without exception, apply to these as well as to *positive* waves, the sign of the coefficient only being changed. We may remark, as a matter which may be observed (in some localities) in daily experience, that the phænomenon of a negative wave is given in great perfection by the paddles of a steam-boat: the first wave which passes away from it being a hollow of considerable depth. We were first made aware of this by observation of the traces made by Mr. Bunt's excellent self-registering tide-gauge on the banks of the Avon, at a short distance below Bristol; but we have since frequently remarked it in the waves caused by steam-boats in other places, merely by watching the fall and rise of the water on the river banks.

Experiments in triangular and trapezoidal channels.

(399.) Experiments were also made by Mr. Russell as to the velocity of transmission of a wave in a channel whose section is a triangle. In some channels which he used the breadth was $\frac{3}{2}\times$ the depth, in others it was $3\times$ the depth; and one side in all cases was vertical. This construction, in conformity with the remark of (222.), could not be expected to give exactly the velocity determined by the formula of (220.). And it is expressly remarked by Mr. Russell that the wave did not stretch across the channel, but travelled in the manner described in (359.). We should therefore expect the experimental velocity of the leading part of the wave (or that corresponding to the deep side) to approach more nearly than the formula of (220.) gives to that of a rectangular channel of the same depth. This is what appears in some degree from the experiments, although their results are irregular. We select a few in which the height of the wave is small. With these we shall give some observations made in trapezoidal channels. In computing all these we shall use the following process. We shall take the undisturbed depth of the water from Mr. Russell's numbers. From this we shall compute the equivalent depth in a rectangular channel, by dividing the area of section by the breadth of the surface (220.). To this we shall add double the height of the wave, as in (395.), and with this sum we shall compute the velocity.

Tabular abstract of experiments.

Triangular Channel H, breadth $= \frac{3}{2} \times$ depth; both sides above the surface of the water being vertical.

Undisturbed Depth in Inches.	Depth of Equivalent Rectangular Channel.	Height of Wave.	Computed Velocity in Feet.	Observed Velocity.
6·04	3·02	0·14	2·80	2·85
7·04	3·52	0·08	2·96	3·03
7·04	3·52	0·11	2·96	3·05
7·04	3·52	0·12	2·97	3·04
Triangular Channel K, breadth = 3 × depth; both sides above the surface of the water being vertical.				
4·04	2·02	0·10	2·39	2·05
4·04	2·02	0·17	2·40	2·28
4·04	2·02	0·37	2·61	2·50
Trapezoidal Channel L, formed by pouring in one additional inch of water into K.				
5·00	3·00	0·24	2·85	3·20
5·00	3·00	0·42	2·99	3·00
5·00	3·00	0·53	3·10	2·90
5·00	3·00	0·68	3·12	3·04
Trapezoidal Channel M, formed by pouring in one inch of water into L.				
6·01	4·01	0·40	3·22	3·08
6·01	4·01	0·86	3·40	3·50

The general agreement with our theory is at least as close as the agreement of the observations among themselves. The mean of all the triangular results, and that of each of the trapezoidal results, agree closely with the theory.

(400.) A series of experiments was made in a channel of uniform depth, whose sides were vertical and met in a vertical line, the horizontal plan of the channel being a triangle with one acute angle. Observations of the height of the wave were made at three stations, at which the breadths of the channel were in the proportion of 4, 2, 1. According to the theory of (254.) and (263.), the heights at these points ought to be in the proportion of $\frac{1}{2}$, $\frac{1}{\sqrt{2}}$, 1. And this proportion very well represents those observed; the inequality being sometimes greater and sometimes less. Thus, comparing the first and third, which ought to be as $\frac{1}{2}$: 1, they are found to be (in the different observations)

1·5 : 3·5
2·0 : 3·3
2·0 : 3·6
1·25 : 2·5
1·5 : 3·25
2·0 : 3·3
1·0 : 2·0
0·25 : 0·4

The velocity cannot be easily calculated, the height of the wave being great in the narrow part of the channel; but it appears, on a general view, to agree well with that in a rectangular channel of the same depth.

(401.) It was always found that the wave broke when its elevation above the general level became equal or nearly so to the general depth. The application of mathematics to this circumstance is so difficult, that we confine ourselves to the mention of the observed fact.

(402.) Observations were also made in a channel (we presume of uniform breadth) whose depth diminished gradually, the bottom being inclined at a slope of 1 in 51. The height of the wave here, in conformity with the theory of (247.) and (264.), ought to be inversely as the fourth root of the depth. The results are irregular, but it is easy to see that this proportion agrees well with the general mean, and that other proportions (for instance, inversely as the depth or as the square root of the depth) would not at all agree with it. Here too it was remarked that the wave broke when its height above the general level was equal to the depth of the water at that place.

(403.) In confirmation of the last remark, observations were made on the surf of the sea, a series of rods being fixed in the sand, by which the height of the wave at the instant of breaking could be observed. The general result was that the wave broke when its height above the antecedent hollow was equal to the depth of the water. Mr. Russell, however, has not stated whether this depth was measured from the mean level of the surface, or from the bottom of the hollow.

(404.) Before dismissing these experiments, however, we must allude to a very remarkable practical fact which led to the whole investigation. It had been accidentally discovered that the navigation of certain canals of small depth, on which boats are drawn by horses, could be greatly facilitated by increasing the speed of the boats; the resistance when the velocity was great being considerably less than when the velocity was small. The whole of the circumstances affecting this result are most ably analyzed by Mr. Russell in a paper in the *Edinburgh Transactions*, vol. xiv. The following general statement will put the reader in possession of the principal facts. There is one particular velocity (that defined by the equation $v^2=gk$) at which a free wave will travel along a canal of given depth k. Nevertheless a boat travelling along a canal, at whatever speed, will be accompanied by a wave travelling with the same speed as the boat, whose motion at that particular speed is maintained by the horizontal pressure of the boat upon the water. These two kinds of waves are in all respects analogous to the free-tide-wave and the forced-tide-wave, of which we have spoken frequently in Section IV., and may with propriety be called the *free-canal-wave* and the *forced-canal-wave*. Now the general fact is this. If the boat moves more slowly than the free wave, the forced wave precedes the middle of the boat, and the force necessary to keep up the speed of the boat is (in proportion to its velocity) considerable. If the boat moves more rapidly than the free wave, the forced wave follows the middle of the boat, and the force necessary to keep up the speed is (in proportion to its velocity) less than in the former case. But if the boat moves with a velocity equal to, or rather slightly exceeding, the velocity of the free wave, then the boat rides with its middle on the top of the wave, and is drawn with a force much less (in proportion to its velocity) than at lower speeds, and even absolutely less. And these are the facts to be explained by our theory.

(405.) The theory of (229.), &c., is sufficient for this purpose. Suppose, as in (232.), the value of X to be 0 when $vt-x$ is <0; and to be $\frac{2b}{3\pi}\left\{\frac{3}{2}\cdot\frac{\pi(vt-x)}{a}-\sin\frac{2\pi(vt-x)}{a}+\frac{1}{8}\sin\frac{4\pi(vt-x)}{a}\right\}$ when $vt-x$ is >0, $<a$: and to be b when $vt-x$ is $>a$: (in which expressions v is not necessarily $=\sqrt{gk}$, but may be any quantity whatever). Since, by (194.), $k+\text{K}=\frac{k}{1+\frac{d\text{X}}{dx}}=k-k\frac{d\text{X}}{dx}$ nearly, we have $\text{K}=-k\frac{d\text{X}}{dx}=\frac{8kb}{3a}\sin^4\frac{\pi(vt-x)}{a}$. This is the elevation of the surface of the water; and, since it applies only from $vt-x=0$ to $vt-x=a$, it shows that through that extent the water will be elevated, its elevation decreasing very gradually at both extremities of the wave. Now in the expressions of (233.) and (234.), suppose a the length of the wave to be so large that the terms depending on $\frac{1}{a^4}$ may be neglected: then the expression for F, the force which is necessary to maintain the motion of the wave with the velocity v, will be found to be

$$\frac{32\,\pi b}{3a^2}(v^2-gk)\,.\,\sin^3\frac{\pi(vt-x)}{a}.\cos\frac{\pi(vt-x)}{a}.$$

Position of the wave with regard to the boat, explained from theory.

(406.) Suppose now the velocity to be less than that of a free wave, or v^2 to be $<gk$. The form of the expression for the necessary force is then $-\text{C}.\sin^3\frac{\pi(vt-x)}{a}.\cos\frac{\pi(vt-x)}{a}$. The changes of sign of this expression depend only on the last term [$\sin\frac{\pi(vt-x)}{a}$ being always positive when $vt-x$ is >0, $<a$]. For the front of the wave, as far as its middle, $vt-x$ is $<\frac{a}{2}$, $\frac{\pi(vt-x)}{a}$ is $<\frac{\pi}{2}$, and F is negative. For the back of the wave, $vt-x$ is $>\frac{a}{2}$, $\frac{\pi(vt-x)}{a}$ is $>\frac{\pi}{2}$, and F is positive. It appears, then, that the wave may be retained at this slow speed if there be a force resisting its front and a force urging forward its back. And it will therefore easily be conceived that (with perhaps a trifling change in the wave's form) a portion of the effect will be produced by only a force urging forward its back. As the motion of a boat can produce no force except forwards, it is readily seen that the boat can produce the force requisite only by following the wave. Thus when the velocity is less than that of a free wave, the wave will precede the boat.

(407.) If the velocity were greater than that of a free wave, or $v^2>gk$, the form of the expression for the force would be $+\text{C}.\sin^3\frac{\pi(vt-x)}{a}.\cos\frac{\pi(vt-x)}{a}$, which would be found to be positive for the front of the wave, and negative for its back. The force therefore to maintain a rapid wave ought to tend to accelerate its front and to retard its back. As before, the boat can produce only the accelerative part, and therefore must be upon the front of the wave, or must be followed by the crest of the wave.

(408.) If $v^2=gk$, no force is requisite. But as we have found in the preceding instances that an accelerating force on the front and a retarding force on the back produce the same effect, we may infer that the combination of an accelerating force in front and an accelerating force on the back will produce no effect, or will produce the same effect as no force, or will make $v^2=gk$. If, then, the head and the stern of the canal-boat equally urged the water, the boat must ride on the top of the wave to maintain this velocity.

(409.) But as the head of the boat urges the water more than the stern does, the velocity of the wave must be such as requires a greater accelerating pressure on the front than on the back, or such as requires a pressure similar to that treated of in (407.), or must be a little greater than the velocity of the free wave, in order that the boat may ride evenly on the crest of the wave. This is true in practice.

Theory of long wave maintained by a force, in its general form.

(410.) There is no difficulty in determining the exact form of the wave which a given force exerted by the boat would produce, provided we suppose it to act equally on all the particles in the same vertical, the wave being long. The equation of (236.), omitting the product of $\frac{d\text{X}}{dx}$ and $\frac{d^2\text{X}}{dx^2}$, becomes $\frac{d^2\text{X}}{dt^2}-gk\frac{d^2\text{X}}{dx^2}=\text{F}$. If we make $gk=v'^2$, v' is the velocity of a free wave. And as F depends upon the position of the boat, and upon the position of any particle of water with respect to the boat, F may be expressed by $\chi''(vt-x)$. Thus the equation becomes

$$\frac{d^2X}{dt^2} - v'^2\frac{d^2X}{dx^2} = \chi''(vt-x).$$

Making $v't-x=u$, $v't+x=w$, as in (197.), we have

$$4v'^2 \cdot \frac{d^2X}{du\,dw} = \chi''\left\{\frac{v+v'}{2v'}u + \frac{v-v'}{2v'}w\right\}.$$

Integrating this with respect to u and w, as in (198.), we have

$$4v'^2X = \phi(u) + \psi(w) + \frac{4v'^2}{v^2-v'^2}\chi\left\{\frac{v+v'}{2v'}u + \frac{v-v'}{2,'}w\right\}$$

or $4v'^2X = \phi(v't-x) + \psi(v't+x) + \frac{4v'^2}{v^2-v'^2}\chi(vt-x)$.

Omitting the two first terms, which express free waves,

$$X = \frac{1}{v^2-v'^2}\chi(vt-x).$$

And $K = -k\frac{dX}{dx} = \frac{k}{v^2-v'^2}\chi'(vt-x)$; or $F = \chi''(vt-x) = \frac{v'^2-v^2}{k} \cdot \frac{dK}{dx}$.

We leave the discussion of this equation to the reader, conceiving that the process which we have used in the last articles is better adapted to the general explanation of the observed facts. We may remark, however, that the breaking of the waves attending the boat, in certain cases, appears to be owing to this circumstance, that the form of the function χ'' is such that the function χ does not satisfy the equations of (229.), and therefore at some point there is an infinite force on the particles of water.

Explanation from theory of the diminution of the resistance to the boat.

(411.) We have not yet, however, alluded to the algebraical circumstances on which the diminution of resistance to the boat depends. For this purpose we will consider the velocities of the individual particles of water. For any particle this is expressed by

$$\frac{dX}{dt} = \frac{2b}{3\pi}\left\{\frac{3\pi}{2a}v - \frac{2\pi v}{a}\cos\frac{2\pi(vt-x)}{a} + \frac{\pi v}{2a}\cos\frac{4\pi(vt-x)}{a}\right\}.$$

When $vt-x=a$ or 0, that is at the beginning or end of the wave, this velocity is

$$\frac{2b}{3\pi}\left\{\frac{3\pi}{2a}v - \frac{2\pi v}{a} + \frac{\pi v}{2a}\right\} = 0.$$

When $vt-x=\frac{a}{2}$, that is at the middle of the wave, this velocity is

$$\frac{2b}{3\pi}\left\{\frac{3\pi}{2a}v + \frac{2\pi v}{a} + \frac{\pi v}{2a}\right\} = \frac{8bv}{3a}.$$

The boat, riding on the top of the wave, has its head and stern almost free of the water, while its middle is immersed in water which is travelling in the same direction as itself with the velocity $\frac{8bv}{3a}$. Consequently the velocity through the water, upon which the resistance depends, is not v but $v-\frac{8bv}{3a}$; and the resistance is therefore diminished in the proportion of $1 : \left(1-\frac{8b}{3a}\right)^2$. To this is owing the great facility of drawing the boat at the high speed, provided it ride on the top of the wave. Perhaps it may be assisted by the circumstance that the head being raised above the water, or rather being left by the water, presents less of bluff resistance than usual. Neither of these circumstances (the rapid motion of the water in the same direction as the boat, and the elevation of the boat's head above the water) presents itself when the boat either precedes or follows the wave.

Section V Account Experiments on Waves.

(412.) It was remarked that at low velocities the boat is followed by a breaking wave, but that at the advantageous velocity there is no broken wave. We cannot undertake to put the explanation of this fact in detail into a mathematical form.

Observations of waves o canals.

(413.) Observations were made by Mr. Russell on the velocity of waves in navigable canals. Their results agree generally with theory; but as the circumstances are never so perfectly known as in artificial canals, we do not think them worthy of the detailed notice which we have given to the others in (392.), &c.

Observations of waves o the sea.

(414.) Mr. Russell also made some observations on the motion of waves of the sea. These observations completely failed. Mr. Russell was not aware that the velocity of waves depends on their lengths, and, in deep water, depends sensibly on nothing else; and was therefore baffled by obtaining the most discordant results. His observations, too, are useless to any other person, as no attempt was made to measure the length of the waves. Observations were, however, made (by immersing a glass tube to a considerable depth in the water) to determine whether the agitation of the water produces a sensible effect at great depths. It was found that where the depth was 12 feet, waves 4 or 5 feet long produce no sensible motion near the bottom; waves 30 or 40 feet long produce a very inconsiderable effect. The reader will see that these results agree perfectly with those of (177.), &c.

(415.) We shall allude hereafter to some of Mr. Russell's observations of tides. Meantime we shall repeat our opinion of the great value of the experiments which we have abstracted, but we must warn the reader against attaching any importance to the theoretical expressions which are mingled with them in the original account.

Gene facts sea-w are n torio

(416.) The general phænomena of waves of the sea, to which we have incidentally alluded in several parts of Section IV., are so notorious that it would be useless and indeed difficult to produce authorities. They are, the great velocity of large waves as compared with that of small ones (168.); the crossing of any number of systems of waves without obliterating each other, (352.) and (354.); the power of the wind to raise the waves, and their broken character during the raising, (271.); the power of the wind to maintain the waves in increasing height from the windward shore, and their smooth character, (267.); the reflection of waves, unbroken, from a vertical wall, (357.); the breaking of the waves on the edge of a shoal, (158.) and (248.); the breaking of the surf on a sloping beach, (249.); and some others.

Spec treat on w of th

We may, however, remark that some treatises have been written expressly on the motion of the waves of the sea, embodying the results of considerable thought and extensive observation, and in some respects worthy of the reader's attention. Among these we may particularly specify those of De la Coudraye, Bremontier, and Emy. The theories of these writers are throughout of very little value, (as will always hold with theories of waves which are not based upon the mathematical expressions of the general properties of fluids:) their observations are, in a great measure, directed to the prac-

Section V. Account of Experiments on Waves.

tical effect of waves, upon sea beaches and erections in the sea. Among those which have a bearing on our theory, we may mention that the horizontal motion of the particles of water next to the bottom, produced in shallow water by long waves (180.), is proved to be sensible by the disturbance of the stones and sand at the bottom; and that the breaking over the edge of a shoal (248.) is stated as occurring on the edge of the bank of Newfoundland when the waves in general are high, although the depth on the shallow side is 500 feet, (that on the deep side being much greater.) We may mention, on the authority of the best charts, that a similar breaking is observed about the line of "no soundings," (that is, where the water suddenly becomes deeper than 600 feet,) which at some distance borders the British Isles. We defer the mention of the bore and other tidal phænomena (to which these authors allude) to our last Section.

Height of waves of the sea.

(417.) The estimations of the height of the greatest waves raised by the wind (272.), which are scattered through the works of different writers, are very unsatisfactory. We are, however, inclined to think that in no circumstances does the height of an unbroken wave exceed 30 or 40 feet.

SECTION VI.—INVESTIGATION OF THE MATHEMATICAL EXPRESSIONS FOR THE TIDES PRODUCED BY THE SUN AND MOON, CONSIDERED AS WAVES IN CANALS.

(418.) In our last section we quitted for a time the main object of this Essay, in order to show that the results of our Theory of Waves are supported by experiment, as far as experiments on the small scale can be found which admit of comparison with them. We now return to our principal object, (to which the remainder of the Essay will be devoted,) and shall employ the present Section in investigating the nature of the tides which would occur if the water were confined in a channel of uniform section and of simple form. The theorems of Section IV., as will appear from the following proposition, will be applicable to this inquiry, as soon as the magnitude of the disturbing forces shall be determined.

(419.) Proposition.—In investigating the motion of the sea in a narrow canal, it is unnecessary to consider the forces arising from the rotation of the Earth.

The general equations for the motion of the waters on the surface of the Earth, whether limited by fixed boundaries or not, are those of (84.), omitting the second for the reasons given in (87.). They are, therefore,

Laplace's equations, applicable to fluids in canals as well as to fluids covering the whole spheroid.

$$\frac{dp'''}{d\theta} = -r^2\frac{d^2u}{dt^2} + 2nr^2.\sin\theta.\cos\theta.\frac{dv}{dt}$$

$$\frac{dp'''}{d\varpi} = -2nr^2.\sin\theta.\cos\theta.\frac{du}{dt} - r^2\sin^2\theta.\frac{d^2v}{dt^2}$$

$$w = -\frac{d}{d\theta}(u\gamma) - u\gamma.\text{cotan}\,\theta - \gamma\frac{dv}{d\varpi}$$

$$= \mathrm{I} + \frac{3\mathrm{Sb}^2}{2\mathrm{D}^3}\left\{(\sin\sigma.\cos\theta + \cos\sigma.\sin\theta.\cos\overline{nt+\varpi-s})^2 - \frac{1}{3}\right\} - gw + p''',$$

where ϖ is the terrestrial longitude (measured from a certain fixed meridian carried by the Earth) of the original or mean place of a particle of water, $\varpi+v$ its longitude as disturbed by tide at the time t; θ is the original angular distance from the north pole, $\theta+u$ the same angle as disturbed by tide at the time t; γ the depth of the water, w its tidal elevation at the time t; n the earth's angular velocity of rotation; p''' that part of the pressure of the particles which depends upon their motion; and the other quantities as in (22.) and (82.). Now it is our object to show that, when these equations are transformed into that shape which applies to the motion of water in a narrow canal, the symbol n will disappear. As this latter is found only in the two first, it will be sufficient for us to show that it disappears from the combination of the two first.

(420.) Now, in investigating the motion of water longitudinally in a narrow canal, putting l for the length of the canal as measured from a fixed point to any particle of water under consideration, we want to find $\frac{dp'''}{dl}$, to be used in the same manner as in (149.) or (195.) To do this by means of the equations above, we must put $\frac{dp'''}{dl} = \frac{dp'''}{d\theta}.\frac{d\theta}{dl} + \frac{dp'''}{d\varpi}.\frac{d\varpi}{dl}$. In figure 29, let BT$=l$, BT$'=l+\delta l$, T and T$'$ being two particles upon a line parallel to the axis of the canal; and let θ, ϖ, and $\theta+\delta\theta$, $\varpi+\delta\varpi$, correspond to the same two particles. Then it is evident that TU$=\mathrm{b}\delta\theta$, UT$'=\mathrm{b}\delta\varpi\times\sin\theta$. Putting T, therefore, for the acute angle at T, we have, $\sin\mathrm{T} = \frac{\mathrm{UT}'}{\mathrm{TT}'} = \frac{\mathrm{b}\delta\varpi\times\sin\theta}{\delta l}$; $\cos\mathrm{T} = \frac{\mathrm{TU}}{\mathrm{TT}'} = \frac{\mathrm{b}\delta\theta}{\delta l}$: or $\frac{\delta\varpi}{\delta l} = \frac{\sin\mathrm{T}}{\mathrm{b}.\sin\theta}$, $\frac{\delta\theta}{\delta l} = \frac{\cos\mathrm{T}}{\mathrm{b}}$. Using these as the values of $\frac{d\varpi}{dl}$ and $\frac{d\theta}{dl}$ in the expression for $\frac{dp'''}{dl}$, we have

$$\frac{dp'''}{dl} = \frac{dp'''}{d\theta}.\frac{d\theta}{dl} + \frac{dp'''}{d\varpi}.\frac{d\varpi}{dl}$$

$$= -\frac{r^2}{\mathrm{b}}\left(\cos\mathrm{T}.\frac{d^2u}{dt^2} + \sin\mathrm{T}.\sin\theta.\frac{d^2v}{dt^2}\right) + \frac{2nr^2}{\mathrm{b}}\left(\cos\mathrm{T}.\sin\theta.\cos\theta.\frac{dv}{dt} - \sin\mathrm{T}.\cos\theta.\frac{du}{dt}\right).$$

Now considering the motion of the water produced by the tide to be only in the direction of the canal's length, and putting L for the displacement of the particle in that direction, it is seen in figure 30 that $\mathrm{b}v.\sin\theta=\mathrm{L}.\sin\mathrm{T}$, or $v=\frac{\mathrm{L}.\sin\mathrm{T}}{\mathrm{b}.\sin\theta}$; and, therefore, $\frac{dv}{dt}=\frac{\sin\mathrm{T}}{\mathrm{b}.\sin\theta}.\frac{d\mathrm{L}}{dt}$, and $\frac{d^2v}{dt^2}=\frac{\sin\mathrm{T}}{\mathrm{b}.\sin\theta}.\frac{d^2\mathrm{L}}{dt^2}$ (omitting, in the differentiation, the terms depending on the differentials of θ and T, because they would introduce the squares of small quantities.) Similarly, $\mathrm{b}u=\mathrm{L}.\cos\mathrm{T}$, or $u=\frac{\mathrm{L}.\cos\mathrm{T}}{\mathrm{b}}$, and $\frac{du}{dt}=\frac{\cos\mathrm{T}}{\mathrm{b}}.\frac{d\mathrm{L}}{dt}$, and $\frac{d^2u}{dt^2}=\frac{\cos\mathrm{T}}{\mathrm{b}}.\frac{d^2\mathrm{L}}{dt^2}$. Substituting these quantities,

$$\frac{dp'''}{dl}=-\frac{r^2}{\mathrm{b}^2}.\frac{d^2\mathrm{L}}{dt^2}=-\frac{d^2\mathrm{L}}{dt^2} \text{ (since b and } r \text{ are sensibly equal).}$$

When the equations are applied to canals, the centrifugal force does not enter.

This equation does not contain n, and, therefore, is unaffected by the Earth's rotation: or, in other words, it is indifferent whether we consider the relative change of place between the point on the Earth and the disturbing luminary to arise, partly from the motion of the Earth and partly from the motion of the luminary, or entirely from the motion of the luminary. (This does not hold when we consider the Earth as covered, in whole or in part, by extensive sheets of water.) The equation, moreover, is exactly the same as if the canal were straight.

(421.) Having established this point, we shall desert this method of investigation, and shall proceed to ascertain the value and effects of the acting forces, as if the Earth were fixed, and the Sun and Moon revolved in diurnal movement round it.

(422.) Problem.—The form of a canal is a small circle upon the Earth, of any diameter, and in any position: the luminary being in any position, it is required to find its force upon the waters at each point, in the direction of the canal's length.

(423.) In figure 31, let He be the small circle, e the point at which the force is to be ascertained, S the place of the luminary: take KF the great circle parallel to the small circle, and therefore passing through E the centre of the sphere: draw SN perpendicular to its plane produced, meeting that plane in N; join EN by the line EFN; take G the centre of the small circle, and draw GH parallel to EF. Since GE is perpendicular to the planes of the circles, or parallel to SN, it is evident that G, E, H, F, S, N, are all in the same plane perpendicular to the plane of the circles. Draw es, en, parallel to ES, EN; join Ee, Se. Let the radius of the small circle, expressed by the angle corresponding to the distance in arc between its pole and its circumference, be α: let the linear radius of the sphere be b; then $\mathrm{GH}=\mathrm{b}.\sin\alpha$, $\mathrm{EG}=\mathrm{b}.\cos\alpha$. Also let ES=D, $\angle\mathrm{GES}=\beta$; then $\mathrm{EN}=\mathrm{D}.\sin\beta$, $\mathrm{SN}=\mathrm{D}.\cos\beta$. And let $\angle\mathrm{HG}e=\theta$. Then, conceiving x to be measured parallel to EN, y perpendicular to it in the plane of the great circle, z parallel to EG, and E to be the origin of co-ordinates, the values of those co-ordinates respectively are as follows:

For S;	$\mathrm{D}.\sin\beta$,	0,	$\mathrm{D}.\cos\beta$.
For e;	$\mathrm{b}.\sin\alpha.\cos\theta$,	$\mathrm{b}.\sin\alpha.\sin\theta$,	$\mathrm{b}.\cos\alpha$;

and, therefore,

$$\begin{aligned}(\mathrm{S}e)^2&=(\mathrm{D}.\sin\beta-\mathrm{b}.\sin\alpha.\cos\theta)^2+(\mathrm{b}.\sin\alpha.\sin\theta)^2+(\mathrm{D}.\cos\beta-\mathrm{b}.\cos\alpha)^2\\&=\mathrm{D}^2-2\mathrm{Db}\,(\cos\beta.\cos\alpha+\sin\beta.\sin\alpha.\cos\theta)+\mathrm{b}^2.\end{aligned}$$

(424.) Now the force which the luminary exerts upon the solid part of the sphere is the same as if the whole matter of the sphere were collected at E, and may, therefore, be represented by $\frac{\mathrm{S}}{(\mathrm{S\,E})^2}$ or $\frac{\mathrm{S}}{\mathrm{D}^2}$ in the direction ES. The force of the luminary upon the particle at e may be represented by $\frac{\mathrm{S}}{(\mathrm{S}e)^2}$ in the direction eS; or by $\frac{\mathrm{S}.e\mathrm{E}}{(\mathrm{S}e)^3}$ in the direction eE, and $\frac{\mathrm{S}.\mathrm{ES}}{(\mathrm{S}e)^3}$ in the direction es parallel to ES. The former of these, by (279.), produces no sensible effect, and may, therefore, be put out of consideration. Hence we have

$$\text{Force upon the solid sphere parallel to ES}\quad=\frac{\mathrm{S}}{\mathrm{D}^2}.$$

$$\text{Force upon the particle at } e \text{ parallel to ES}\quad=\frac{\mathrm{S}.\mathrm{D}}{(\mathrm{S}e)^3}.$$

Excess of the latter above the former, which is the true relative disturbing force upon the particle at e,

$$=\mathrm{S}\left(\frac{\mathrm{D}}{(\mathrm{S}e)^3}-\frac{1}{\mathrm{D}^2}\right).$$

(425.) This, however, is the disturbing force in the direction es. If we resolve it into two parts, one parallel to en and one perpendicular to it, or parallel to eg, the latter will be entirely transverse to the direction of the canal at that point, and will, therefore, in our investigation be rejected: the former will be found by multiplying the force in the direction es by $\cos sen$ or $\sin\beta$. Thus we have

$$\text{Disturbing force in the direction } en\quad=\mathrm{S}\left(\frac{\mathrm{D}}{(\mathrm{S}e)^3}-\frac{1}{\mathrm{D}^2}\right)\sin\beta.$$

Tides and Waves.

(426.) Finally, resolving this force into two, one parallel to Ge, and the other perpendicular to it, or tangential to the small circle (and, therefore, urging the water along the canal), we find for the latter,

Expression for the disturbing force produced by the Sun or Moon on the water of a canal.

$$\text{Disturbing force in the direction of the canal at } e = \mathrm{S}\left(\frac{\mathrm{D}}{(\mathrm{S}e)^3} - \frac{1}{\mathrm{D}^2}\right)\sin\beta.\sin\theta.$$

Putting for $\frac{1}{(\mathrm{S}e)^3}$ the expression $\left\{\mathrm{D}^2 - 2\mathrm{Db}(\cos\beta.\cos\alpha + \sin\beta.\sin\alpha.\cos\theta) + \mathrm{b}^2\right\}^{-\frac{3}{2}}$, and expanding to the second power of b, the expression becomes

$$\mathrm{S}.\sin\beta.\sin\theta\left\{\frac{3\mathrm{b}}{\mathrm{D}^3}(\cos\beta.\cos\alpha + \sin\beta.\sin\alpha.\cos\theta) - \frac{3}{2}.\frac{\mathrm{b}^2}{\mathrm{D}^4} + \frac{15}{2}.\frac{\mathrm{b}^2}{\mathrm{D}^4}(\cos\beta.\cos\alpha + \sin\beta.\sin\alpha.\cos\theta)^2\right\}.$$

This force acts to urge the water in the direction eH. We shall, however, conceive the length of the canal to be measured positively in the same direction in which θ is measured positively, that is, from H towards e: and this gives for the proper expression for the disturbing force,

$$\mathrm{S}.\sin\beta.\sin\theta\left\{-\frac{3\mathrm{b}}{\mathrm{D}^3}(\cos\beta.\cos\alpha + \sin\beta.\sin\alpha.\cos\theta) + \frac{3}{2}.\frac{\mathrm{b}^2}{\mathrm{D}^4} - \frac{15}{2}.\frac{\mathrm{b}^2}{\mathrm{D}^4}(\cos\beta.\cos\alpha + \sin\beta.\sin\alpha.\cos\theta)^2\right\}.$$

(427.) Problem.—To find the expression for the force as varying with the time, the luminary being supposed to revolve uniformly in a small circle.

Let Ppo, figure 32, be a sphere whose centre is the centre of the earth, and whose circumference passes through the circle oS in which the luminary revolves: let P be the pole of the circle oS (it will, therefore, in fact be the point corresponding to the pole of the earth): and let p be the point corresponding to the pole of the canal; let P, p, o, O, E, G, be in the same plane; and let p, S, H, E, G, be in the same plane; let O be the origin of the angle or arc for the canal Oe; and let o be the origin of the angle or arc for the small circle oS. The spherical angle opS is evidently equal to OGH. Let OGe=ϕ: this angle is independent of the position of S, and may, therefore, be properly used for defining the point e. The angle θ in the investigation above is HGe, or ϕ−OGH, or $\phi - op$S, figures 32 and 33; β or GES is represented on the sphere by pS; α is here a constant. We will put 90°−σ for Po or PS (σ is then the declination of the luminary); and δ for Pp; and nt for the angle oPS, which is proportional to the time.

(428.) Now our expressions above depend on $\sin\beta.\sin\theta$, $\cos\beta$, and $\sin\beta.\cos\theta$; and these we must endeavour to express so as to contain no variable but nt.

First,
$$\sin\beta.\sin\theta = \sin p\mathrm{S}.\sin(\phi - op\mathrm{S})$$
$$= \sin\phi.\sin p\mathrm{S}.\cos op\mathrm{S} - \cos\phi.\sin p\mathrm{S}.\sin op\mathrm{S}.$$

Now
$$\cos op\mathrm{S} = -\cos \mathrm{P}p\mathrm{S} = \frac{\cos\beta.\cos\delta - \sin\sigma}{\sin\beta.\sin\delta} \text{ (figure 33.)};$$

therefore
$$\sin p\mathrm{S}.\cos op\mathrm{S} = \frac{\cos\beta.\cos\delta - \sin\sigma}{\sin\delta} = \frac{\cos\delta(\sin\sigma.\cos\delta + \cos\sigma.\sin\delta.\cos nt) - \sin\sigma}{\sin\delta}$$
$$= \cos\sigma.\cos\delta.\cos nt - \sin\sigma.\sin\delta.$$

And
$$\sin p\mathrm{S}.\sin op\mathrm{S} = \sin\mathrm{PS}.\sin o\mathrm{PS} = \cos\sigma.\sin nt;$$

therefore
$$\sin\beta.\sin\theta = -\sin\sigma.\sin\delta.\sin\phi + \cos\sigma.\cos\delta.\sin\phi.\cos nt - \cos\sigma.\cos\phi.\sin nt.$$

Second,
$$\cos\beta = \sin\sigma.\cos\delta + \cos\sigma.\sin\delta.\cos nt.$$

Third,
$$\sin\beta.\cos\theta = \sin p\mathrm{S}.\cos(\phi - op\mathrm{S}) = \cos\phi.\sin p\mathrm{S}.\cos op\mathrm{S} + \sin\phi.\sin p\mathrm{S}.\sin op\mathrm{S}$$
$$= -\sin\sigma.\sin\delta.\cos\phi + \cos\sigma.\cos\delta.\cos\phi.\cos nt + \cos\sigma.\sin\phi.\sin nt.$$

Fourth. By means of the two last we obtain $\cos\alpha.\cos\beta + \sin\alpha.\sin\beta.\cos\theta =$
$$\cos\alpha.\sin\sigma.\cos\delta - \sin\alpha.\sin\sigma.\sin\delta.\cos\phi + \cos\alpha.\cos\sigma.\sin\delta.\cos nt + \sin\alpha.\cos\sigma.\cos\delta.\cos\phi.\cos nt$$
$$+ \sin\alpha.\cos\sigma.\sin\phi.\sin nt.$$

Expressions which must be multiplied to give the disturbing force in terms of the time.

And the first and fourth are now to be substituted in the expression at the end of (426.).

It is evident that this would lead to results of great complexity; and we shall content ourselves, therefore, with applying it to a few special cases.

(429.) (I.) Suppose the luminary in the equator, or $\sigma = o$.

Disturbing body supposed to be in the equator, the canal forming any small circle.

In this case
$$\sin\beta.\sin\theta = \cos\delta.\sin\phi.\cos nt - \cos\phi.\sin nt.$$
$$\cos\alpha.\cos\beta + \sin\alpha.\sin\beta.\cos\theta = \cos\alpha.\sin\delta.\cos nt + \sin\alpha.\cos\delta.\cos\phi.\cos nt + \sin\alpha.\sin\phi.\sin nt.$$

The product of these two expressions, with sign changed, which represents the principal part of the disturbing force, is

$$-\frac{1}{2}\cos\alpha.\sin\delta.\cos\delta.\sin\phi.(1 + \cos 2nt) - \frac{1}{2}\sin\alpha.\cos^2\delta.\sin\phi.\cos\phi(1 + \cos 2nt)$$

$$-\frac{1}{2}\sin\alpha.\cos\delta.\sin^2\phi.\sin 2nt+\frac{1}{2}\cos\alpha.\sin\delta.\cos\phi.\sin 2nt+\frac{1}{2}\sin\alpha.\cos\delta.\cos^2\phi.\sin 2nt$$
$$+\frac{1}{2}\sin\alpha.\sin\phi.\cos\phi.(1-\cos 2nt).$$

This expression consists of three distinct classes of terms:

Disturbance of mean level.

(430.) The first or $-\frac{1}{2}\cos\alpha.\sin\delta.\cos\delta.\sin\phi+\frac{1}{2}\sin\alpha.\sin^2\delta.\sin\phi.\cos\phi$, does not depend on nt, and therefore does not give rise to any oscillation, or any state of waters varying with the time. But as it depends on ϕ, it shows, (152.) and (283.), that the relative mean level in different parts of the canal is not the same as if the luminary did not exist.

(431.) The second, or $-\frac{1}{2}\cos\alpha.\sin\delta.\cos\delta.\sin\phi.\cos 2nt+\frac{1}{2}\cos\alpha.\sin\delta.\cos\phi.\sin 2nt$, depends on ϕ and $2nt$. Putting it in the form $A.\sin\overline{2nt+\phi}+B.\sin\overline{2nt-\phi}$, or $(A+B)\sin 2nt.\cos\phi+(A-B)\cos 2nt.\sin\phi$, we easily find for its equivalent

$$\cos\alpha.\sin^3\frac{\delta}{2}.\cos\frac{\delta}{2}.\sin\overline{2nt+\phi}+\cos\alpha.\sin\frac{\delta}{2}.\cos^3\frac{\delta}{2}.\sin\overline{2nt-\phi}.$$

If x be the length of the canal measured from the same origin as ϕ, $\phi=\frac{x}{b\sin\alpha}$, and this expression becomes

$$\cos\alpha.\sin^3\frac{\delta}{2}.\cos\frac{\delta}{2}.\sin\overline{2nt+\frac{x}{b\sin\alpha}}+\cos\alpha.\sin\frac{\delta}{2}.\cos^3\frac{\delta}{2}.\sin\overline{2nt-\frac{x}{b\sin\alpha}}.$$

Each of these two terms is of the same form as those considered in (274.), putting H for the multiplier here, nt for $2nt$, and mx for $\pm\frac{x}{b\sin\alpha}$; and each will give rise to a wave, one of which will roll in one direction and the other in the opposite direction. If we examine the expression for Y at the surface, or K, in (279.), and (284.), and remark that for these two waves m has different signs, we shall see that the two coefficients above will be multiplied by equal factors with opposite signs; the absolute sign of either depending upon the depth of the water. The whole elevation of the water then, produced by these two waves, will be represented by

$$\frac{kb\sin\alpha.\cos\alpha.\sin\delta}{8n^2b^2\sin^2\alpha-2gk}\times\left\{\sin^2\frac{\delta}{2}.\cos\overline{2nt+\frac{x}{b\sin\alpha}}-\cos^2\frac{\delta}{2}.\cos\overline{2nt-\frac{x}{b\sin\alpha}}\right\},$$

or
$$\frac{kb.\sin\alpha.\cos\alpha.\sin\delta}{8n^2b^2\sin^2\alpha-2gk}\times\{-\cos\delta.\cos\phi.\cos 2nt-\sin\phi.\sin 2nt\}.$$

If we make $\tan\psi=\frac{\tan\phi}{\cos\delta}$, this becomes

$$-\frac{kb.\sin\alpha.\cos\alpha.\sin\delta}{8n^2b^2\sin^2\alpha-2gk}\times\sqrt{\cos^2\delta.\cos^2\phi+\sin^2\phi}.\cos\overline{2nt-\psi},$$

where it must be remembered that k is the depth of the water, and that the multiplier $\frac{3Sb}{D^3}$ has been omitted.

First semidiurnal tide.

This expression shows, 1st, that *for the same place* the oscillation goes through all its phases while $2nt$ changes by 2π, and therefore the oscillation goes twice through all its phases while $2nt$ changes by 4π, or while nt changes by 2π, or while the luminary performs its revolution; that is, the tide is semidiurnal. 2nd, that *for the same time* the oscillation has all its different phases for values of ψ extending through 2π, that is for values of ϕ extending through 2π (for ϕ and ψ have the values $0, \frac{\pi}{2}, \pi, \frac{3\pi}{2}, 2\pi$, together), that is, for the whole extent of the canal and for no smaller extent; therefore there is but one wave on the canal, which passes round it with an irregular motion twice in a tidal day. 3rd, that the magnitude of the fluctuation is different at different places.

But as the expression contains the factors $\cos\alpha.\sin\delta$, this wave has no existence unless the canal is a small circle whose pole does not coincide with the pole of the earth.

(432.) The third class of terms, or $-\frac{1}{4}\sin\alpha(1+\cos^2\delta)\sin 2\phi.\cos 2nt+\frac{1}{2}\sin\alpha.\cos\delta.\cos 2\phi.\sin 2nt$, depends upon 2ϕ and $2nt$. Putting it in the form $A.\sin\overline{2nt+2\phi}+B.\sin\overline{2nt-2\phi}$, it becomes

$$-\frac{1}{2}\sin\alpha.\sin^4\frac{\delta}{2}.\sin\overline{2nt+2\phi}+\frac{1}{2}\sin\alpha.\cos^4\frac{\delta}{2}.\sin\overline{2nt-2\phi};$$

which, as above, will produce an elevation of waters represented by

$$-\frac{1}{4}.\frac{kb.\sin^2\alpha}{n^2b^2\sin^2\alpha-gk}\left\{\sin^4\frac{\delta}{2}.\cos\overline{2nt+2\phi}+\cos^4\frac{\delta}{2}.\cos\overline{2nt-2\phi}\right\},$$

or
$$-\frac{1}{4}.\frac{kb\sin^2\alpha}{n^2b^2\sin^2\alpha-gk}\left\{\left(\frac{1}{2}+\frac{1}{2}\cos^2\delta\right)\cos 2\phi.\cos 2nt+\cos\delta.\sin 2\phi.\sin 2nt\right\}.$$

If $\tan\chi = \frac{2\cos\delta}{1+\cos^2\delta}\tan 2\phi$, this becomes

$$-\frac{1}{4}\cdot\frac{kb\sin^2\alpha}{n^2b^2\sin^2\alpha - gk}\times\sqrt{\left(\frac{1}{2}+\frac{1}{2}\cos^2\delta\right)^2.\cos^2 2\phi + \cos^2\delta.\sin^2 2\phi}.\cos\overline{2nt-\chi},$$

to which the multiplier $\frac{3Sb}{D^3}$ is yet to be supplied.

Second semi-diurnal tide.

This expression shows, 1st, that *for the same place* the oscillation goes through all its phases while $2nt$ changes by 2π, or is semidiurnal; 2nd, that *for the same time* the oscillation has all its different phases for values of χ extending through 2π, that is, for values of 2ϕ extending through 2π; or it has all its different phases twice repeated for values of χ extending through 4π, that is for values of ϕ extending through 2π; therefore there is a double wave on the canal which passes round it with an irregular motion once in a tidal day; 3rd, that the magnitude of the fluctuation is different in different places.

These two are compounded into one semi-diurnal tide at every place.

(433.) The two waves which we have found will produce only one apparent semidiurnal wave at each place. For the expressions $L.\cos\overline{2nt-\psi} + M.\cos\overline{2nt-\chi}$ or $(L\cos\psi + M\cos\chi)\cos 2nt + (L\sin\psi + M\sin\chi)\sin 2nt$ may be represented by $N.\cos\overline{2nt-O}$ where $N = \sqrt{\{(L\cos\psi + M\cos\chi)^2 + (L\sin\psi + M\sin\chi)^2\}}$ and $\tan O = \frac{L\sin\psi + M\sin\chi}{L\cos\psi + M\cos\chi}$; which, as estimated at the place, presents the appearance of a single semidiurnal tide-fluctuation. As the relation of the coefficients of the two waves, and even the similarity or opposition of their signs, will depend on the depth of the canal and other special circumstances, we cannot proceed further in the investigation.

(434.) There is no term depending on nt, and therefore no diurnal wave.

The canal supposed to be a great circle in any position, and the disturbing body in any position.

(435.) (II.) Suppose the canal to be a great circle, or $\alpha = 90°$; the position of the great circle and the declination of the luminary being any whatever. (We shall, for convenience, assume this case in all our succeeding investigations.)

In this case $\sin\beta.\sin\theta = -\sin\sigma.\sin\delta.\sin\phi + \cos\sigma.\cos\delta.\sin\phi.\cos nt - \cos\sigma.\cos\phi.\sin nt$;

and $\cos\alpha.\cos\beta + \sin\alpha.\sin\beta.\cos\theta = -\sin\sigma.\sin\delta.\cos\phi + \cos\sigma.\cos\delta.\cos\phi.\cos nt + \cos\sigma.\sin\phi.\sin nt$.

If we multiply these terms with sign changed, we find in the result the following classes of terms.

Disturbance of mean level.

(436.) First, the terms $\left(-\sin^2\sigma + \frac{1}{2}\cos^2\sigma\right)\sin^2\delta.\sin\phi.\cos\phi$ independent of nt. These, as before, do not indicate an oscillation, but they show that the mean elevation of the water at each place is modified by the attraction of the luminary. And as the extent of this modification depends on σ, there will be a slow change in the mean elevation of the water depending on the slow changes of σ. The elevation will however be the same for equal values of σ with opposite signs. Introducing the factor $S.\frac{3b}{D^3}$, putting $\left(\frac{1}{2} - \frac{3}{2}\sin^2\sigma\right)$ for $-\sin^2\sigma + \frac{1}{2}\cos^2\sigma$, and observing that $\phi = \frac{x}{b}$, x being the length of the canal, the actual elevation, by (152.) is

$$+\frac{3Sb}{2gD^3}\left(\frac{1}{2} - \frac{3}{2}\sin^2\sigma\right)\sin^2\delta\int_x \sin 2\phi$$

or

$$+\frac{3Sb^2}{2gD^3}\left(\frac{1}{2} - \frac{3}{2}\sin^2\sigma\right)\sin^2\delta\int_\phi \sin 2\phi,$$

or

$$-\frac{3Sb^2}{4gD^3}\left(\frac{1}{2} - \frac{3}{2}\sin^2\sigma\right)\sin^2\delta.\cos 2\phi.$$

The part which depends on σ is $+\frac{9Sb^2}{8gD^3}\sin^2\sigma.\sin^2\delta.\cos 2\phi$. Now $\sin\sigma =$ sine of declination of luminary; and ϕ is 0 or 180°, or $\cos 2\phi = 1$, for those parts of the canal which have the greatest geographical latitude; consequently at those parts the mean level of the water rises when the declination of the luminary is greatest; it falls by the same amount at the equator.

Computation in feet.

(437.) To estimate it in feet we may remark, that this coefficient for the Sun is $\frac{9}{4}$ of the coefficient computed in (31.), or $\frac{9}{4}\times 0{\cdot}2710$ foot, or 0·61 foot. Therefore when the Sun's declination is σ, the elevation of the water depending on these terms, produced by the Sun, is 0·61 foot $\times \sin^2\sigma.\sin^2\delta.\cos 2\phi$. If the canal pass through the pole, $\sin\delta = 1$, and the expression is 0·61 foot $\times \sin^2\sigma.\cos 2\phi$. As ϕ in this case is measured from the pole, the expression shows that the water is raised at the poles by 0·61 foot $\times \sin^2\sigma$, and is lowered at the equator by the same quantity.

(438.) If we put M for the mass of the Moon, D′ for her distance, and μ for her declination, the corresponding quantity for the effect of the Moon's action will be $\frac{9\text{M}\text{b}^2}{8g\text{D}'^3}\sin^2\mu.\sin^2\delta.\cos 2\phi$. Observing that (if the Moon's mass be supposed $\frac{1}{80}$ of the Earth's) this coefficient is $\frac{9}{4}$ of that computed in (35.), the numerical coefficient is $\frac{9}{4}\times 0\cdot 5959$ foot or $1\cdot 34$ foot; and the elevation of the water is $1\cdot 34$ foot $\times \sin^2\mu.\sin^2\delta.\cos 2\phi$.

(439.) Secondly, there are the following terms depending on nt and 2ϕ

$$\sin\sigma.\cos\sigma.\sin\delta.(\cos\delta.\sin 2\phi.\cos nt-\cos 2\phi.\sin nt)$$

or

$$-\sin\sigma.\cos\sigma.\sin\delta.\left(\sin^2\frac{\delta}{2}.\sin\overline{nt+\frac{2x}{\text{b}}}+\cos^2\frac{\delta}{2}.\sin\overline{nt-\frac{2x}{\text{b}}}\right).$$

As before, the effects of these two terms will be represented by two waves, one moving in one direction and the other in the opposite direction; and the elevation produced by both will be represented by

$$\frac{2k\text{b}.\sin\sigma.\cos\sigma.\sin\delta}{n^2\text{b}^2-4gk}\left(-\sin^2\frac{\delta}{2}.\cos\overline{nt+\frac{2x}{\text{b}}}+\cos^2\frac{\delta}{2}.\cos\overline{nt-\frac{2x}{\text{b}}}\right)$$

or by

$$\frac{2k\text{b}.\sin\sigma.\cos\sigma.\sin\delta}{n^2\text{b}^2-4gk}.(\cos\delta.\cos nt.\cos 2\phi+\sin nt.\sin 2\phi).$$

Let $\tan\psi=\frac{\tan 2\phi}{\cos\delta}$; then the expression for the elevation becomes

$$\frac{2k\text{b}.\sin\sigma.\cos\sigma.\sin\delta}{n^2\text{b}^2-4gk}\times\sqrt{\cos^2\delta.\cos^2 2\phi+\sin^2 2\phi}\times\cos\overline{nt-\psi}$$

which is to be multiplied by $\frac{3\text{Sb}}{\text{D}^3}$.

Diurnal tide; it depends on the declination of the disturbing body, and disappears if the body is in the equator.

From this expression it appears, 1st, that *for the same place* the oscillation of the water goes through all its phases while nt increases by 2π, or while the luminary goes round the earth; it is therefore a diurnal tide; 2nd, that *for the same time* the wave is in all its different stages for the extent through which ψ varies by 2π, or through which 2ϕ varies by 2π, and is therefore to be found twice in all its different stages for the extent through which ϕ varies by 2π; or there are two complete waves upon the canal, going round it once in two days, with an irregular motion; 3rd, that the amount of oscillation is different at different places; 4th, that, other circumstances being the same, the extent of the oscillation is proportional to the sine of twice the luminary's declination, and changes sign when the declination changes from north to south, and vanishes when the luminary is in the equator.

When the canal is equatorial there is no diurnal tide.

(440.) There are two cases that deserve distinct notice.

1st. If the canal is equatorial, $\delta=0$, and the whole expression vanishes; or, whatever be the declination of the luminary, there is no diurnal tide.

2nd. If the canal passes through the poles of the earth, $\delta=90°$, and the expression is reduced to

$$\frac{2k\text{b}.\sin\sigma.\cos\sigma}{n^2\text{b}^2-4gk}\sin nt.\sin 2\phi$$

When the canal passes through the poles, the tide-wave is a stationary wave.

or the wave is a stationary wave, such as is treated of in (187.). Its period is diurnal; there are two waves always existing at the same time. The origin of ϕ is, in this case, at the pole; and there will therefore be no vertical oscillation at the poles, (where $2\phi=0$ or $360°$,) and none at the equator, (where $2\phi=180°$ or $540°$,) but there will be a large oscillation at latitude $\pm 45°$ (where $2\phi=90°$, $270°$, $450°$, or $630°$). An elevation in north latitude occurs at the same time as a depression in south latitude. The origin of nt is the plane which passes through the axis of the earth and the axis of the canal; and the water is therefore in its mean state, as depends on this diurnal wave, when the luminary is six hours from the meridian, and in its most elevated or depressed state when the luminary is on the meridian. The elevation or depression depends on the sign of $\sin\sigma$ or sine of declination; it depends also on the sign of $n^2\text{b}^2-4gk$, which will vary as the canal is deep or shallow.

(441.) Thirdly, there are terms depending on $2nt$ and 2ϕ, namely,

$$\frac{1}{2}\cos^2\sigma.\cos\delta.\cos 2\phi.\sin 2nt-\frac{1}{4}\cos^2\sigma.(1+\cos^2\delta).\sin 2\phi.\cos 2nt,$$

or

$$-\frac{1}{2}\cos^2\sigma.\sin^4\frac{\delta}{2}.\sin\overline{2nt+2\phi}+\frac{1}{2}\cos^2\sigma.\cos^4\frac{\delta}{2}.\sin\overline{2nt-2\phi},$$

Semi-diurnal tide, different in different parts of the canal.

which produce two waves travelling in opposite directions, the sum of the corresponding elevations fo which will be represented by

$$-\frac{1}{4}.\frac{k\text{b}.\cos^2\sigma}{n^2\text{b}^2-gk}\left\{\sin^4\frac{\delta}{2}.\cos\overline{2nt+2\phi}+\cos^4\frac{\delta}{2}.\cos\overline{2nt-2\phi}\right\}$$

or by

$$-\frac{1}{4}.\frac{kb.\cos^2\sigma}{n^2b^2-gk}\left\{\left(\frac{1}{2}+\frac{1}{2}\cos^2\delta\right).\cos 2nt.\cos 2\phi+\cos\delta.\sin 2nt.\sin 2\phi\right\}.$$

ect. VI. xpres- ns for Tides idered Waves Canals.

Making $\tan\chi=\frac{2\cos\delta}{1+\cos^2\delta}\tan 2\phi$, this becomes

$$-\frac{1}{4}.\frac{kb.\cos^2\sigma}{n^2b^2-gk}\sqrt{\left(\frac{1}{2}+\frac{1}{2}\cos^2\delta\right)^2.\cos^2 2\phi+\cos^2\delta.\sin^2 2\phi}.\cos\overline{2nt-\chi}$$

which is to be multiplied by $\frac{3Sb}{D^3}$.

From this it is readily seen; 1st, that the tide is semidiurnal; 2nd, that there are two waves on the canal at the same time, revolving irregularly in a day; 3rd, that the extent of oscillation is different in different parts of the canal; 4th, that it is in all proportional to the square of the cosine of the luminary's declination.

If the canal is equatorial, the tide is equal in all parts.

(442.) If the canal is equatorial, $\delta=0$, $\cos\delta=1$, and the expression becomes

$$-\frac{3Sb}{4D^3}.\frac{kb\cos^2\sigma}{n^2b^2-gk}\cos\overline{2nt-2\phi},$$

or the extent of oscillation is everywhere the same, and the water is high or low on the meridian under the luminary according as gk is greater or less than n^2b^2.

If the canal passes through the poles, the wave is a stationary wave.

(443.) If the canal pass through the pole, $\delta=90^\circ$, $\cos\delta=0$, and the expression is reduced to

$$-\frac{3Sb}{8D^3}.\frac{kb\cos^2\sigma}{n^2b^2-gk}\cos 2\phi.\cos 2nt,$$

which shows that there is a stationary wave at each pole and at each intersection with the equator, the high water at the pole corresponding to the low water at the equator. The extreme phases of the oscillation occur when the luminary is on the meridian of the canal, and when it is in the meridian six hours from that of the canal; if n^2b^2 be greater than gk, it is high water at the equator and low water at the poles in the former of the cases, and low water at the equator and high water at the poles in the latter case.

Relation of the sign of the expressions to the depth of the sea.

(444.) The reader will remark that gk is less than n^2b^2 if $\frac{k}{b}$ is less than $\frac{n^2b}{g}$, or if $\frac{\text{depth of sea}}{\text{earth's radius}}$ is less than $\frac{\text{equatorial centrifugal force}}{\text{gravity}}$, or less than $\frac{1}{289}$; or if the depth of the sea is less than 14 miles. And $4gk$ is less than n^2b^2 if $\frac{k}{b}$ is less than $\frac{n^2b}{4g}$, or if the depth of the sea is less than $3\frac{1}{2}$ miles. In this calculation we suppose n the apparent angular velocity of the luminary to be not sensibly different from the real angular velocity of the earth; this applies very nearly to the sun and nearly enough to the moon.

(445.) In the expression for the force urging the water along the canal, we have preserved the terms depending on $\frac{b^2}{D^4}$. We do not however think that the examination of the effects of substituting in these expressions the values found in (428.) or (429.) or (435.) would repay us for the trouble. The additional factor $\frac{b}{D}$ is about $\frac{1}{60}$, and the terms multiplied by this factor are of the same order as those already discussed, so that the new terms may be considered as of magnitude corresponding to $\frac{1}{60}$ part of those already found (more or less). The terms depending on nt and $2nt$ are nearly similar to those already found; the only novelty is, that there are terms depending on $3nt$. But as these terms are evidently small, and as observation has not yet given reason to suppose that there is a sensible sea-tide occurring three times every day, we shall not further consider these terms.

(446.) Now it must be remarked, that the coefficient of each of the terms which we have discussed is slowly variable. The coefficient of the term examined in (439.) depends on $\frac{\sin\sigma.\cos\sigma}{D^3}$; that of the term in (441.) depends on $\frac{\cos^2\sigma}{D^3}$; where σ is the declination of the sun (or moon), and D its distance; two elements which are continually varying. The elements, however, and the combinations of them which we have just set down, may be expanded (by the usual astronomical developments) in such series as $H+H'\cos i't+$ &c., where, for $\frac{\sin\sigma.\cos\sigma}{D^3}$, H is 0; and, for $\frac{\cos^2\sigma}{D^3}$, H is much larger than H'. In the latter of these cases, which applies to the semidiurnal tide, supposing the force only to vary, the coefficient of elevation or depression, by (288.), Variation of the disturbing body's distance and of its angular velocity considered.

would not sensibly differ from $\frac{km}{i^2-gkm^2}(\mathrm{H}+\mathrm{H}'\cos i't)$, which is the same as that corresponding to the position of the luminary at the time of the tide, supposing the elevation or depression computed from that position as if it remained constant; but the time of high or low water would be sensibly different. But in reality, when the force varies from change of the attracting body's distance from perigee and of declination, its angular motion varies at the same time: it will be convenient, then, to consider the effect of these two causes together. Now the reader will perceive that in (427.) and all the articles following it, we have used nt merely to denote the hour-angle of the attracting body; and, therefore, upon supposing that angle to increase irregularly, we must, in (427.) &c., put a new symbol. Thus we shall put $-\frac{3}{2}\cdot\frac{\mathrm{Sb}\cos^2\sigma}{\mathrm{D}^3}\cdot\sin^4\frac{\delta}{2}\cdot\sin\overline{2\text{ hour-angle}+2\phi}$ for the first term in (441.); or $-\frac{3}{2}\cdot\frac{\mathrm{Sb}\cos^2\sigma}{\mathrm{D}^3}\sin^4\frac{\delta}{2}\cdot\sin\overline{2\text{ hour-angle}+2\frac{x}{\mathrm{b}}}$. Now let e be the eccentricity of the orbit in which the body moves round the earth, ht its mean anomaly, ω the inclination of its orbit to the earth's equator, lt its mean distance from the intersection of its orbit with the equator. Then, as its true right ascension may be expressed very nearly by the formula,

$$\text{mean right ascension}+2e\sin ht-\frac{\omega^2}{4}\sin 2lt,$$

its true hour-angle may be expressed very nearly by

$$nt-2e\sin ht+\frac{\omega^2}{4}\sin 2lt;$$

and the expression above becomes

$$-\frac{3}{2}.\mathrm{Sb}.\sin^4\frac{\delta}{2}\times\frac{\cos^2\sigma}{\mathrm{D}^3}.\sin\overline{2nt+\frac{2x}{\mathrm{b}}-4e\sin ht+\frac{\omega^2}{2}\sin 2lt}.$$

Expanding the sine, and remarking that, when z is small, $\sin\overline{2nt+\frac{2x}{\mathrm{b}}+z}$ is expressed with sufficient accuracy by

$$\sin\left(2nt+\frac{2x}{\mathrm{b}}\right)+z.\cos\left(2nt+\frac{2x}{\mathrm{b}}\right),$$

the expression becomes

$$-\frac{3}{2}\mathrm{Sb}\sin^4\frac{\delta}{2}\times\frac{\cos^2\sigma}{\mathrm{D}^3}\times\left\{\sin\left(2nt+\frac{2x}{\mathrm{b}}\right)-2e.\sin\left(2nt+ht+\frac{2x}{\mathrm{b}}\right)+2e.\sin\left(2nt-ht+\frac{2x}{\mathrm{b}}\right)\right.$$
$$\left.+\frac{\omega^2}{4}\sin\left(2nt+2lt+\frac{2x}{\mathrm{b}}\right)-\frac{\omega^2}{4}\sin\left(2nt-2lt+\frac{2x}{\mathrm{b}}\right)\right\}.$$

(447.) Now $\cos^2\sigma=1-\sin^2\sigma=1-\omega^2.\sin^2 lt$ nearly $=1-\frac{\omega^2}{2}+\frac{\omega^2}{2}\cos 2lt$. And, putting D_m for the mean distance, as in (22.), $\mathrm{D}=\mathrm{D}_m(1-e.\cos ht)$ nearly, or $\frac{1}{\mathrm{D}^3}=\frac{1}{\mathrm{D}_m^3}(1+3e.\cos ht)$ nearly; therefore $\frac{\cos^2\sigma}{\mathrm{D}^3}=\frac{1-\frac{\omega^2}{2}}{\mathrm{D}_m^3}\times\left(1+3e.\cos ht+\frac{\omega^2}{2}\cos 2lt\right)$ nearly. Substituting this, the expression above becomes

$$-\frac{3}{2}\left(1-\frac{\omega^2}{2}\right).\frac{\mathrm{Sb}}{\mathrm{D}_m^3}.\sin^4\frac{\delta}{2}\times\left\{\sin\overline{2nt+\frac{2x}{\mathrm{b}}}-\frac{e}{2}\sin\overline{2nt+ht+\frac{2x}{\mathrm{b}}}+\frac{7e}{2}\sin\overline{2nt-ht+\frac{2x}{\mathrm{b}}}+\frac{\omega^2}{2}\sin\overline{2nt+2lt+\frac{2x}{\mathrm{b}}}\right\};$$

and the corresponding expression for the elevation of the water, omitting the constant factor $-3\left(1-\frac{\omega^2}{2}\right).\frac{\mathrm{Sb}^2k}{\mathrm{D}_m^3}\sin^4\frac{\delta}{2}$, is

$$\frac{1}{4n^2\mathrm{b}^2-4gk}\cos\overline{2nt+\frac{2x}{\mathrm{b}}}-\frac{1}{(2n+h)^2\mathrm{b}^2-4gk}.\frac{e}{2}\cos\overline{2nt+ht+\frac{2x}{\mathrm{b}}}+\frac{1}{(2n-h)^2\mathrm{b}^2-4gk}.\frac{7e}{2}.\cos\overline{2nt-ht+\frac{2x}{\mathrm{b}}}$$
$$+\frac{1}{(2n+2l)^2\mathrm{b}^2-4gk}.\frac{\omega^2}{2}.\cos\overline{2nt+2lt+\frac{2x}{\mathrm{b}}}.$$

Expression for the elevation of the tide, with force and angular velocity variable.

(448.) Expanding this expression to the first power of h and l, and omitting the constant factor $\frac{1}{4n^2\mathrm{b}^2-4gk}$, it may be put in the form $\mathrm{P}.\cos\overline{2nt+\frac{2x}{\mathrm{b}}}+\mathrm{Q}.\sin\overline{2nt+\frac{2x}{\mathrm{b}}}$, where

$$\mathrm{P}=1+\left(3+\frac{16n\mathrm{b}^2h}{4n^2\mathrm{b}^2-4gk}\right)e.\cos ht+\left(\frac{1}{2}-\frac{4n\mathrm{b}^2l}{4n^2\mathrm{b}^2-4gk}\right)\omega^2.\cos 2lt$$

$$Q=\left(4+\frac{12n\mathrm{b}^2h}{4n^2\mathrm{b}^2-4gk}\right)e.\sin ht+\left(-\frac{1}{2}+\frac{4n\mathrm{b}^2l}{4n^2\mathrm{b}^2-4gk}\right)\omega^2.\sin 2lt\,;$$

and this may be put in the form $R.\cos\overline{2nt+\frac{2x}{\mathrm{b}}-T}$, or $R.\cos\overline{2nt+2\phi-T}$, wher $R=\sqrt{P^2+Q^2}=P$ nearly, and $T=4e.\sin ht-\frac{\omega^2}{2}\sin 2lt$ nearly.

(449.) If the magnitude of the wave had been computed on the supposition that the force was constant and equal to that given by the values of D and σ for the time of computation, the expression would have been merely $\left(1+3e\cos ht+\frac{\omega^2}{2}\cos 2lt\right)\times\cos\overline{2nt+\frac{2x}{\mathrm{b}}}$. It appears, therefore, that one effect of introducing the motions which we have considered is, to increase the term (in the coefficient of elevation of tides) which depends on the eccentricity of the orbit, or to make the tide proportional to a higher power than the cube of the parallax (supposing the depth of the sea less than 14 miles); another effect is, to diminish the term depending on the declination, or to make the tide proportional to a lower power than the square of the cosine of declination (on the same supposition): a third effect is, to make the phase of tide depend on $\overline{2nt-4e\sin ht+\frac{\omega^2}{2}\sin 2lt+2\phi}$ nearly, or on $\overline{2\text{ true hour-angle }+2\phi}$. The hour-angle, however, is to be computed with an increased value of ellipticity of the moon's orbit, and a diminished obliquity. The same remarks apply, in all respects, to the term depending on $\overline{2nt-2\phi}$, and therefore to their combination.

Modifications to be made in the computation proceeding on the supposition of constant force.

The terms in the moon's longitude and distance depending on the evection (which is but a slowly varying eccentricity of the moon's orbit) follow the same law as those depending on the eccentricity, so nearly that the same investigations may be held to apply to them, without farther examination. The law of the inequality called *Variation* is a little different. If the inequality in the moon's distance depending on variation be called $-D_m.p.\cos qt$, that in longitude will be $+\frac{11}{8}p.\sin qt$, or that in hour-angle will be $-\frac{11}{8}.p.\sin qt$. Treating these terms in the same manner as those above, it will be found that there is added to P the term $\left(3+\frac{11n\mathrm{b}^2q}{4n^2\mathrm{b}^2-4gk}\right)p.\cos qt$, and to Q the term $\left(\frac{11}{4}+\frac{12n\mathrm{b}^2q}{4n^2\mathrm{b}^2-4gk}\right)p.\sin qt$. The second term within each of these brackets bears to the first a proportion which is not exactly the same as that for the terms depending on e, but is not very different from it; and, as the numerical value of Variation is small, there will be no sensible error in assuming that it is exactly the same. Thus, the remarks which we have made regarding the term depending on the eccentricity apply also to the evection and variation: the term depending on the obliquity following a different law. There is no other inequality in the moon's motion worthy of notice.

(450.) To examine the effect of friction, we will neglect the square of f in the expression of (325.); and putting i successively $=2n$, $2n+h$, $2n-h$, and $2n+2l$; $v^2=gk$, $m=\frac{2}{\mathrm{b}}$, and omitting the same constant factor as in (447.), we have the following terms to add to those at the end of (447.):

Friction taken into account.

$$-\frac{f\mathrm{b}^2 2n}{(4n^2\mathrm{b}^2-4gk)^2}\sin\overline{2nt+\frac{2x}{\mathrm{b}}}+\frac{f\mathrm{b}^2(2n+h)}{((2n+h)^2.\mathrm{b}^2-4gk)^2}.\frac{e}{2}\sin\overline{2nt+ht+\frac{2x}{\mathrm{b}}}$$

$$-\frac{f\mathrm{b}^2(2n-h)}{((2n-h)^2\mathrm{b}^2-4gk)^2}.\frac{7e}{2}.\sin\overline{2nt-ht+\frac{2x}{\mathrm{b}}}-\frac{f\mathrm{b}^2(2n+2l)}{((2n+2l)^2\mathrm{b}^2-4gk)^2}.\frac{\omega^2}{2}.\sin\overline{2nt+2lt+\frac{2x}{\mathrm{b}}}\,;$$

which, if expanded to the first power of h and l, may be put in the form $P'.\sin\overline{2nt+\frac{2x}{\mathrm{b}}}+Q'.\cos\overline{2nt+\frac{2x}{\mathrm{b}}}$, where

$$P'=\frac{f\mathrm{b}^2}{4n^2\mathrm{b}^2-4gk}\left\{-2n-\left(6n+4h\,\frac{12n^2\mathrm{b}^2+4gk}{4n^2\mathrm{b}^2-4gk}\right)e.\cos ht-\left(n-2l\,\frac{6n^2\mathrm{b}^2+2gk}{4n^2\mathrm{b}^2-4gk}\right)\omega^2.\cos 2lt\right\}$$

$$Q'=\frac{f\mathrm{b}^2}{4n^2\mathrm{b}^2-4gk}\left\{\left(8n+h\,\frac{36n^2\mathrm{b}^2+12gk}{4n^2\mathrm{b}^2-4gk}\right)e.\sin ht+\left(-n+l\,\frac{12n^2\mathrm{b}^2+4gk}{4n^2\mathrm{b}^2-4gk}\right)\omega^2.\sin 2lt\right\};$$

the additional factor $\frac{1}{4n^2\mathrm{b}^2-4gk}$ being omitted, as in (448.). It is easily seen that

$$P'=-P\times\frac{2nf\mathrm{b}^2}{4n^2\mathrm{b}^2-4gk}-f\mathrm{b}^2h\,.\,\frac{16n^2\mathrm{b}^2+16gk}{(4n^2\mathrm{b}^2-4gk)^2}e.\cos ht+f\mathrm{b}^2l\,\frac{4n^2\mathrm{b}^2+4gk}{(4n^2\mathrm{b}^2-4gk)^2}\omega^2.\cos 2lt$$

$$Q'=Q\times\frac{2nf\mathrm{b}^2}{4n^2\mathrm{b}^2-4gk}+f\mathrm{b}^2h\,.\,\frac{12n^2\mathrm{b}^2+12gk}{(4n^2\mathrm{b}^2-4gk)^2}e.\sin hl+f\mathrm{b}^2l\,\frac{4n^2\mathrm{b}^2+4gk}{(4n^2\mathrm{b}^2-4gk)^2}\omega^2.\sin 2lt.$$

(451.) If we combine these terms with those of (448.), introducing some terms of the order f^2eh and $f^2\omega^2l$ (which are perfectly insensible), and if we make $\frac{f\mathrm{b}^2}{4n^2\mathrm{b}^2-4gk}=\rho$, $\frac{f\mathrm{b}^2(4n^2\mathrm{b}^2+4gk)}{(4n^2\mathrm{b}^2-4gk)^2}=\rho_{\prime}$, it will be found that the complete expression for the height of the water at any instant, omitting the factors $-3\left(1-\frac{\omega^2}{2}\right)\frac{\mathrm{Sb}^2k}{\mathrm{D}_m^3}\sin^4\frac{\delta}{2}\frac{1}{4n^2\mathrm{b}^2-4gh}$, is

Alteration which it produces in the last expression.

$$\{\cos(2nt+2\phi)-2n\rho\,.\sin(2nt+2\phi)\}\times\left\{1+\left(3+\frac{16n\mathrm{b}^2h}{4n^2\mathrm{b}^2-4gk}\right)e\,(\cos ht+h\rho_{\prime}.\sin ht)\right.$$
$$\left.+\left(\frac{1}{2}-\frac{4n\mathrm{b}^2l}{4n^2\mathrm{b}^2-4gk}\right)\omega^2(\cos 2lt+2l\rho_{\prime}.\sin 2lt)\right\}$$
$$+\{\sin(2nt+2\phi)+2n\rho\,.\cos(2nt+2\phi)\}\times\left\{\left(4+\frac{12n\mathrm{b}^2h}{4n^2\mathrm{b}^2-4gk}\right)e\,(\sin ht-h\rho_{\prime}.\cos ht)\right.$$
$$\left.+\left(-\frac{1}{2}+\frac{4n\mathrm{b}^2l}{4n^2\mathrm{b}^2-4gk}\right)\omega^2(\sin 2lt-2l\rho_{\prime}.\cos 2lt)\right\};$$

or

$$\cos\overline{2n(t+\rho)+2\phi}\times\left\{1+\left(3+\frac{16n\mathrm{b}^2h}{4n^2\mathrm{b}^2-4gk}\right)e.\cos\overline{h(t-\rho_{\prime})}+\left(\frac{1}{2}-\frac{4n\mathrm{b}^2l}{4n^2\mathrm{b}^2-4gk}\right)\omega^2.\cos\overline{2l(t-\rho_{\prime})}\right\}$$
$$+\sin\overline{2n(t+\rho)+2\phi}\times\left\{\left(4+\frac{12n\mathrm{b}^2h}{4n^2\mathrm{b}^2-4gk}\right)e.\sin\overline{h(t-\rho_{\prime})}+\left(-\frac{1}{2}+\frac{4n\mathrm{b}^2l}{4n^2\mathrm{b}^2-4gk}\right)\omega^2.\sin\overline{2l(t-\rho_{\prime})}\right\}.$$

May be represented by using the elements of an earlier epoch, and then adding a constant to the phase of the tide.

(452.) The interpretation of this expression is as follows:

The tides, as affected by friction, may still be computed by the formula of (449.), provided that first we take the co-ordinates of the attracting body's place, not for the time for which the calculation is made, but for a time anterior to it by $\rho_{\prime}$; and, secondly, that, having thus computed the time of any phase of the tide (high water, for instance), we adopt a time earlier than the time so found, by ρ.

(453.) In the case of the diurnal tide, for which the coefficient has the form $\mathrm{H}'.\cos i't$, and in which the phases of tide depend on $it\pm mx$ where $i=n$ and $m=\frac{2}{\mathrm{b}}$ (439.), we think it is desirable to call the reader's attention to the circumstance that the approximate expressions in (286.), (287.), and (289.), may not apply. For, these expressions suppose that i^2-gkm^2 or $n^2-\frac{4gk}{\mathrm{b}^2}$ is large, or that $\frac{n^2\mathrm{b}}{g}-\frac{4k}{\mathrm{b}}$ is large. Now we have seen that this quantity vanishes if the depth of the sea is $3\frac{1}{2}$ miles, and changes sign if the depth is still greater. Our knowledge of the depth of the sea is extremely imperfect, but, such as it is, it entitles us to suppose that the depth may equal or exceed $3\frac{1}{2}$ miles. In this case it will be necessary to resort to the expressions at the end of (289.), and it will be found that it may happen that the greatest diurnal tide will occur on the day when the force which causes it is smallest. We think it unnecessary to remark on the time at which the high or low diurnal tide occurs, because that time has not been a subject of accurate observation.

Effects of two bodies considered.

(454.) We shall now consider the tides in a canal caused by the simultaneous action of two bodies, as the sun and the moon. We shall consider all the symbols of the present Section, up to this point, as applying to the sun, and (as in Section II.) shall put M for the mass of the moon, μ for its declination, and D' for its distance. And, n being the apparent angular motion of the sun round the earth in its diurnal motion, we shall find n' for the apparent angular motion of the moon round the earth, where $\frac{n'}{n}=\frac{29}{30}$ nearly, and $\left(\frac{n'}{n}\right)^2=\frac{14}{15}$ nearly. It will be convenient to compare our conclusions with those of the equilibrium-theory.

(455.) First, in regard to the ordinary semidiurnal tide. The coefficient of solar tide is $-\frac{3}{4}.\frac{\mathrm{S}k\mathrm{b}^2\cos^2\sigma}{\mathrm{D}^3(n^2\mathrm{b}^2-gk)}$, (441.), omitting those factors which depend only on the position of the canal and of the place of observation upon it; the coefficient of lunar tide is $-\frac{3}{4}.\frac{\mathrm{M}k\mathrm{b}^2\cos^2\mu}{\mathrm{D}'^3(n'^2\mathrm{b}^2-gk)}$. Hence,

$$\text{the lunar coefficient} = \text{solar coefficient} \times \frac{\mathrm{M}\cos^2\mu}{\mathrm{D}'^3}\times\frac{\mathrm{D}^3}{\mathrm{S}\cos^2\sigma}\times\frac{n^2\mathrm{b}^2-gk}{n'^2\mathrm{b}^2-gk}.$$

But by the equilibrium-theory (44.), the lunar coefficient = solar coefficient $\times\frac{\mathrm{M}'}{\mathrm{S}'}\left(\frac{\mathrm{P}'}{\mathrm{P}'_m}\right)^2.\left(\frac{\mathrm{P}_m}{\mathrm{P}}\right)^3.\frac{\cos^2\mu}{\cos^2\sigma}$, which upon substituting from the articles preceding (44.) becomes

$$\text{lunar coefficient} = \text{solar coefficient} \times \frac{\mathrm{M}\cos^2\mu}{\mathrm{D}^3}\times\frac{\mathrm{D}^3}{\mathrm{S}\cos^2\sigma}:$$

Consequently the proportion of the lunar coefficient to the solar coefficient given by the wave-theory is greater than that given by the equilibrium-theory in the ratio of $n^2 \mathrm{b}^2 - gk$ to $n'^2 \mathrm{b}^2 - gk$, or in the ratio of $\frac{n^2 \mathrm{b}}{g} - \frac{k}{\mathrm{b}}$ to $\left(\frac{n'}{n}\right)^2 \cdot \frac{n^2 \mathrm{b}}{g} - \frac{k}{\mathrm{b}}$, or in the ratio of $\cdot 00346 - \frac{k}{\mathrm{b}}$ to $\cdot 00323 - \frac{k}{\mathrm{b}}$. Any probable supposition that we may make in regard to the depth of the sea will give for this ratio a value sensibly different from that of equality. Suppose, for instance, the sea were 4 miles deep; then $\frac{k}{\mathrm{b}} = \cdot 001$ nearly, and the ratio is $\cdot 00246 : \cdot 00223$, or $11 : 10$ nearly. The mass of the moon, therefore, as inferred from the tides with a sea 4 miles deep would be too great by $\frac{1}{10}$ part. If the sea were 8 miles deep, the ratio would be $\cdot 00146 : \cdot 00123$, or $13 : 11$ nearly, and the inferred mass of the moon would be too great by $\frac{1}{6}$ part. Thus we find,

The solar and lunar tides are not proportional to to the solar and lunar force: the lunar tide being too great.

1st. If the depth of the sea is less than 14 miles, the mass of the moon inferred from the tides is inevitably too great.

2d. The error will be different (or the moon's mass will appear different) in canals of different depths.

The excess different in canals of different depth.

(456.) In regard to the variations of these coefficients as produced by the variations of distance and declination, the equilibrium-theory requires that those coefficients be used which correspond to the actual distance, &c., of the sun and moon at the moment: the wave-theory with friction requires that coefficients be used which correspond to an earlier time, preceding the tide by $\frac{f}{4} \cdot \frac{\frac{n^2 \mathrm{b}^2}{g^2} + \frac{k}{g}}{\left(\frac{n^2 \mathrm{b}}{g} - \frac{k}{\mathrm{b}}\right)^2}$. This applies at present to the coefficients only.

(457.) In regard to the mode of combining these coefficients, the equilibrium-theory, (44.) and (49.), putting M_2 and S_2 for the coefficients, gives for the height of tide at any instant $\mathrm{M}_2 . \cos 2 . \overline{l - m} + \mathrm{S}_2 . \cos 2 . \overline{l - s}$, or

$$\sqrt{\{\mathrm{M}_2^2 + 2 \mathrm{M}_2 \mathrm{S}_2 . \cos 2 . \overline{m - s} + \mathrm{S}_2^2\}} \times \cos \overline{2 (l - m)} + \mathrm{F},$$

$$\text{where } \tan \mathrm{F} = \frac{\mathrm{S}_2 . \sin 2 . \overline{m - s}}{\mathrm{M}_2 + \mathrm{S}_2 . \cos 2 . \overline{m - s}},$$

$l - m$ being the moon's hour angle, $l - s$ the sun's hour angle, and therefore $m - s$ being the excess of the sun's hour angle above the moon's at the instant of computation for tide. The wave-theory gives in the first instance (441.) for the sun $\mathrm{S}_2 . \cos \overline{2 nt - \chi}$, for the moon $\mathrm{M}_2 . \cos \overline{2 n' t - \chi}$: but these receive some modifications. Both forces are variable, but (on account of the extreme slowness of the variations for the sun) it will be sufficient to consider those of the moon. Both tides are affected by friction, and this must be taken into account for both. Referring then to the expressions at the end of (451.), to the explanation in (452.), and to the formula of (449.), it will be seen that we have to combine two such expressions as the following:

For the Sun $\quad \mathrm{S}_2 . \cos \overline{2nt + 2n\rho - \chi}$.

For the Moon $\quad \mathrm{M}_2 . \cos \overline{2n't + 2n'\rho' - \mathrm{T} - \chi}$,

S_2, M_2, and T, being certain functions of the bodies' co-ordinates at a time anterior by $\rho_{\prime} = \frac{f \mathrm{b}^2 (4n^2 \mathrm{b}^2 + 4gk)}{(4n^2 \mathrm{b}^2 - 4gk)^2}$; and ρ being $= \frac{f \mathrm{b}^2}{4n^2 \mathrm{b}^2 - 4gk}$, and $\rho' = \frac{f \mathrm{b}^2}{4n'^2 \mathrm{b}^2 - 4gk}$.

Combining these as in (49.), an expression will be found exactly similar to that of (49.) cited above, but in which the angle entering in the second term of the coefficient, and in the expression for F, instead of $2 . \overline{m - s}$, is

$$(2n - 2n') \, t + \frac{2nf}{4n^2 - gk \frac{4}{\mathrm{b}^2}} - \frac{2n'f}{4n'^2 - gk \frac{4}{\mathrm{b}^2}} + \mathrm{T}.$$

(458.) If we expand the third term by putting $n' = n + (n' - n)$, and retain only the first power of $(n' - n)$, the expression for the angle becomes

$$(2n - 2n') \, t - \frac{f}{4} \cdot \frac{\frac{n^2 \mathrm{b}^2}{g^2} + \frac{k}{g}}{\left(\frac{n^2 \mathrm{b}}{g} - \frac{k}{\mathrm{b}}\right)^2} (2n - 2n') + \mathrm{T},$$

$$\text{or} \qquad (2n - 2n') \times \left\{ t - \frac{f}{4} \cdot \frac{\frac{n^2 \mathrm{b}^2}{g^2} + \frac{k}{g}}{\left(\frac{n^2 \mathrm{b}}{g} - \frac{k}{\mathrm{b}}\right)^2} + \frac{\mathrm{T}}{2n - 2n'} \right\}.$$

Since $2nt$ is the sun's mean hour angle from a certain plane at the time t, and $2n't$ is the moon's mean hour angle from the same plane, $(2n-2n')\,t$ is the difference of their mean hour angles or the difference of their mean right ascensions at the time t. Consequently the angle above is the difference of mean right ascensions of the sun and moon, not at the time t, but at the time

$$t-\frac{f}{4}\cdot\frac{\frac{n^2 b^2}{g^2}+\frac{k}{g}}{\left(\frac{n^2 b}{g}-\frac{k}{b}\right)^2}+\frac{T}{2n-2n'},$$

or it is the difference of *true* right ascensions at the time $t'=t-\frac{f}{4}\cdot\frac{\frac{n^2 b^2}{g^2}+\frac{k}{g}}{\left(\frac{n^2 b}{g}-\frac{k}{b}\right)^2}$.

The relative positions of the two bodies at an anterior time are to be used in the calculation of tide as affected by friction.

(459.) The second term shows as the effect of friction that we may calculate the height and time of high water on the equilibrium-theory, (the constant χ excepted,) provided we consider the Sun and Moon to have the relative position which they really had at the time preceding the time of tide by $\frac{f}{4}\cdot\frac{\frac{n^2 b^2}{g^2}+\frac{k}{g}}{\left(\frac{n^2 b}{g}-\frac{k}{b}\right)^2}$, or $\rho_{\prime}$. It is singular that this quantity (although found by a very different process) should be exactly the same as the quantity found in (452.) for the retroposition of time for which the coefficients are to be computed. The combination of results shows that both the coefficients and the relative positions are to be used which correspond to a time anterior by a certain quantity.

(460.) With regard to the diurnal tide, we leave the reader to make similar remarks. We will only observe that as the coefficients of the diurnal and of the semidiurnal tide depend in very different ways on the depth of the sea, it is impossible, without a precise knowledge of the depth, to assign any proportion between the coefficients as depending on the proportion of the forces.

Effect of propagation of tide up a river considered.

(461.) Suppose now that a shallow river, or even a shoaly sea of considerable length, communicates with such a canal as we have supposed. The insignificance of such a river will prevent it from altering the tides of the sea in the smallest sensible degree; and we may consider the sole effect of their communication to be, that the sea will always maintain at the mouth of the river the height given by the preceding theory, and that it will always supply or receive the water necessary for the propagation up the river of such waves as are consistent with the circumstances of the river. The only points to which we shall now allude are, the time and height of the tides during the different parts of a lunation.

The relation of the height of the river-tide to the height of the sea-tide always the same.

(462.) With regard to the height of the tide: the highest tide at the station on the river will always be that which is propagated from the highest tide of the sea. The tide occupies always the same time in passing from the sea to the river station (with a small inequality, perhaps of a few minutes, which, although important in the next article, is quite unimportant for our present purpose). The effect of this is only to require a greater retroposition of the places of the sun and moon by which the magnitude of the tide is computed. Thus, suppose that for the sea-tide it is necessary to compute for places of the sun and moon earlier by forty-four hours, and suppose that the tide-wave occupies three hours in passing up the river: then the height of high water at the inland station must be computed from the positions of the sun and moon forty-seven hours earlier than the time of high water at the inland station; because that time is forty-four hours earlier than the time of high water in the sea-tide by which the river-tide is produced.

The relation of the time of the river-tide to the time of the sea-tide not always the same.

(463.) But for the calculation of the time of high water a different rule is necessary. It will be seen by (206.) that the time of high water at the inland station, as measured from a certain fixed phase of the tide at the shore, is $\frac{3\pi}{2mv}+\frac{x'}{v}-\frac{3x'}{2v}b$, or $C-\frac{3x'}{2v}b$, where b is the proportion of the rise of tide above the mean state to the mean depth of water in the river. The quantity b therefore will be proportional to $\sqrt{\{M_2^2+2M_2S_2\cos\overline{2(A'-A)}+S_2^2\}}$, where A' is the moon's right ascension and A the sun's, computed for t', the time whose expression is at the end of (458.); or supposing S_2 much smaller than M_2, b will be proportional to $M_2+S_2\cos\overline{2(A'-A)}$. Substituting this in $C-\frac{3x'}{2v}b$, it takes the shape $E-Gx'.\cos\overline{2(A'-A)}$. Now the time of high water on the sea-coast is determined by making $\cos\overline{2n't-\chi'+F}$ maximum, where $F=\frac{S_2}{M_2}\sin\overline{2(A'-A)}$ nearly; and where $\chi'=\chi+T-\frac{2n'.f}{4n'^2-gk\frac{4}{b}}$. As this requires that $2n't-\chi'+F=2m\pi$, m being a whole number, we have the time of high water on the coast $=\frac{2m\pi+\chi'}{2n'}-\frac{F}{2n'}=\frac{2m\pi+\chi'}{2n'}-\frac{S_2}{2n'M_2}\sin\overline{2(A'-A)}$, and therefore the time of high ect. VI. xpres- ions for Tides idered Waves Canals.

water at the inland station =

$$\frac{2m\pi+\chi'}{2n'}+E-\frac{S_2}{2n'M_3}\sin\overline{2(A'-A)}-Gx'\cos\overline{2(A'-A)}.$$

Let $\frac{2m\pi+\chi'}{2n'}+E=K$, $\sqrt{\left(\frac{S_2}{2n'M_2}\right)^2+G^2x'^2}=L$, and $\frac{2n'M_2Gx'}{S_2}=\tan N$: then the time of high water at the inland station is

$$K-L\sin\overline{2(A'-A)+N}.$$

Now $\overline{2(nt-n't)+N}$, or $(2n-2n')\left(t'+\frac{N}{2n-2n'}\right)$ is the difference of mean right ascension of the sun and the moon at the time $t'+\frac{N}{2n-2n'}$; therefore $\overline{2(A'-A)+N}$ is very nearly the difference of true right ascension of the sun and moon at that time. Thus it appears that for computing the time of high water it is necessary to use, not the positions of the sun and moon at the true time of the tide, nor the positions at that anterior time which is employed in computing the height of high water, but a time later than that which is used for computing the height, and therefore a time which is nearer to the true time of high water.

The time for a river-tide is to be computed with the places of the Sun and Moon corresponding to a later epoch than that used for the heights.

(464.) It appears also that the effect of the passage of the tide along the shallow river, as shown by the variation in the time of high water as referred to the moon's transit, if computed by the formulæ of the equilibrium-theory, is to give a mass of the moon which is a little smaller than that corresponding to the variation of heights. For we adopt the quantity L as the representative of $\frac{S_2}{2n'M_2}$; but L really is $\sqrt{\left(\frac{S_2}{2n'M_3}\right)^2+G^2x'^2}$: therefore we adopt for $\frac{S_2}{2n'M_3}$, a quantity which is too great, or for M_2, a quantity which is too small.

The mass of the Moon inferred from these times of tide will be a little too large.

(465.) If we investigated the effect of the passage up the shallow river upon the time of low water, we should find that the positions of the sun and moon corresponding to an earlier time than that used for the height of the high water must be employed; but we should still find that the mass of the moon inferred from the variations of the time of low water as referred to the moon's transit is too small.

Modification in the statement for the times of low water.

(466.) We shall here close our exposition of the Wave-Theory as applied to the tides. As nearly the whole of this theory is published for the first time in the present treatise, we shall not remark upon it at great length. We think it right, however, to point out to the reader its great and important defect as applied to the explanation of tides upon the earth, namely, that in the case of nature the water is not distributed over the surface of the globe in canals of uniform breadth and depth, or in any form very nearly resembling them. In this regard its fundamental suppositions are probably as much, or nearly as much, in error as those of Laplace's theory. But we also think it right to point out that in regard to the completeness of detail with which the principles can be followed out, there is no comparison between the two theories. This will be seen by the reader who has remarked the facility with which the results of "difference between the angular velocities of the sun and moon," "variable coefficients of force," and "friction," are obtained in finite form. For these, Laplace's theory is quite useless. And though (as we have stated) the fundamental suppositions differ much from the real state of the seas, yet no one can hesitate to admit that the same general conclusions will appply:—for instance, that the moon's mass inferred from the height of the tides is too great, and by different degrees in different places: that the effect of friction will be a retroposition of tides in reference to the places of the sun and moon, &c. The peculiarities of river-tides, which no other theory has touched upon, are almost completely mastered by this.

Advantages and disadvantages of the theory of waves as applied to tides.

(467.) With these remarks we terminate our Theory of Tides. Any mathematical deduction which may be required in reference to any special phænomenon of observation will be given in the place where such phænomenon is mentioned. The remainder of our Essay will be devoted to the Observations of Tides and their Comparison with the Theory.

SECTION VII.—METHODS USED FOR OBSERVING THE TIDES, AND FOR REDUCING THE OBSERVATIONS.

(468.) The greater part of the observations of tides hitherto made have been observations of time and height of high water only, made at the entrances of the docks of our principal commercial towns. These observations, as regards *time*, are all affected by the circumstance treated in (208.) and (463.), namely, that the time of transmission of the tide from the sea is less for a large tide than for a small one; and, as regards *height*, they do not even give the coefficient of vertical oscillation. Both these defects are removed by adding observations of time and height of low water: and such a system of observation, if made under favourable circumstances, and where the water is quiet, will usually give results of considerable accuracy for the times of high and low water on the coast.

(469.) But this supposes that the rise of the water is continuous and its fall continuous, and that both follow simple laws; a thing which is by no means to be assumed, and which we shall find incorrect in application to various instances. Moreover, as regards time, it is inaccurate, because it is impossible to fix precisely on the time when the surface of the water, having risen with a decreasing velocity that at last is imperceptible, begins to fall with a velocity which at first is insensibly

Observations of time of greatest height and greatest depression are inaccurate.

Mr. Whewell's proposed method of observation.

Objections to that method.

small. To obviate the latter inconvenience, it was proposed by Mr. Whewell that the time should be noted at which the surface of the water passes any fixed points on a wall in its ascent and in its descent. If the rise and fall followed the same simple law as in the sea, (the elevation above a mean point being expressed by sin nt,) the time intermediate to these observed times would give the time of high or low water with precision, because the instant at which the water passes the line, when in rapid rise or fall, can be very accurately observed. But in fact, the laws of rise and fall are so different that this deduction would be erroneous for high water, and very greatly in error for low water. The author of this paper endeavoured to use, for the time of low water, observations of height made at equal intervals of time for an hour and half in the neighbourhood of and including low water, but even in that time the fall and rise occurred with such different velocities that it was necessary to abandon the use of the mean of any of the times, and to judge as well as could be done, under all circumstances, from the general course of the fall and rise during the whole interval.

It is highly important to observe the whole course of the tide.

(470.) There is no method, in fact, which will give satisfactory results as to low and high water, and none which gives any knowledge whatever of the general course of the tide, except the observation—by the senses of an observer stationed for the purpose, or by the indications of a self-registering tide-gauge—of the height of the water at every instant of time, or at least of the height at very small intervals. When a self-registering instrument is established, it is as easy to keep it in action constantly as occasionally, and thus the register of every tide may be preserved. When the observations of a special observer are used, it is necessary to limit the observations, either to two or three days which exhibit the principal changes of circumstance, (as a day near spring tides and a day near neap tides,) or to a period which embraces those changes (as a half-lunation). We shall mention the cautions with which both kinds of observations ought to be made, and shall notice the principles of construction of a self-registering tide-gauge.

Caution necessary for accurate observation.

(471.) The first thing is, to obtain a surface of water, communicating so freely with the sea as to assume the same mean level, and yet unaffected by the agitations of ordinary waves. A sheltered situation ought therefore to be chosen; but, in parts opening immediately to the sea, it is necessary to use other precautions. The most effectual is, to place in the water a large vertical trunk or trough, communicating with the water only by a small hole at or near to its bottom. Suppose, for instance, this hole to be 10 feet below the surface; the agitation of the water by waves 10 feet long is, by (178.), diminished to $\frac{1}{535}$ part of that at the surface, and therefore would not sensibly disturb the water in the trunk even if there were no limitation of the communicating aperture. But if a wave be very long—as for instance any of the modifications of the tide wave—then the agitation caused by it is as great at 10 feet depth as at the surface (180.), and its time is so great that it will be able always to maintain the water in the trunk sensibly at the same level as the external water, even though the communicating aperture be small. If then a float be placed in the trunk, carrying an index above, this index will rise or fall with the general mean level of the water as affected by the tides only. We have had great pleasure in watching the steady motion of the index on the admirable tide-gauge erected at the Royal Dockyard of Sheerness, while the swell on the outside was so heavy that to judge of a mean level within the accuracy of many inches appeared quite impracticable. The instrument, however, is more likely to fail for observations near low water. For suppose the surface to drop till the hole is only one foot below the surface, then the motion of the water produced by waves 10 feet long is nearly as great as that at the surface, and therefore, however much the aperture be limited, irregularity in the height of the surface will be produced by the waves. The only simple way of preventing this is to let the bottom of the trunk and its communicating aperture be carried as low as possible below low water. It might perhaps be advisable to have the trunk divided into two chambers by a vertical partition, the first chamber receiving the water from the sea by a small hole in its bottom, the second receiving the water from the first by a small hole in the partition; the motion of the water in the second would be extremely steady. It is almost needless to observe that a fixed vertical scale of feet and inches, or other measures of length, is indispensable; in simple observations it may be traced upon the quay wall or post at which the elevation of the surface is noted; where a float carries a vertical rod, the rod may be marked as a scale of feet and inches, and the indication opposite to a fixed index may be noted, or the rod may carry an index which in rising or falling will point to different divisions on a fixed scale.

Sect. V Method used fo observi the Tic and fo reducin the Ob rations

(472.) In some of these ways, observations of the height and time of high water (and for the most part of low water also) are regularly made by direction of the Board of Admiralty at Portsmouth, Plymouth, Ramsgate, Liverpool, Dublin, and occasionally at Harwich and other ports when maritime surveys are in progress. Observations of the same kind are also usually made at the principal docks in the Thames, the Mersey, and the Clyde, as well as at other ports. The principal data for determinations of the time, &c., of tides in ports all over the world have been obtained by some of these methods, either from the loose observations made by harbour-masters and merchant-sailors, or from the more accurate observations conducted by the officers of government surveying-ships.

Gen prin of se regi tide-

(473.) The principle of the self-registering tide-gauge is in all cases the following. By means of a pendulum-clock urged by a sufficient weight, a sheet of paper either spread upon a flat surface, or rolled as required upon a large cylinder, or fixed in a tubular form upon a solid cylinder, is made to travel uniformly. The first of these methods is used for Osler's anemometer, in which the self-registering principle is similar to that of a tide-gauge; the second in Palmer's tide-gauge, (*Phil. Trans.* 1831;) the third in Bunt's tide-gauge. A pencil, carried by mechanism connected with the float, is made to move through a space proportional to the vertical motion of the float, and in a direction perpendicular to the direction of the paper's motion (where the paper is on a cylinder, the motion of the pencil is parallel to the cylinder's axis). A curve is thus traced, whose abscissa represents time, and whose ordinate represents rise of the surface of the water. Occasional examination is always necessary to verify the correctness of action of the machinery. We cannot perhaps do better than copy (with some alterations) from the *Phil. Trans.* 1838, the description of Mr. Bunt's tide-gauge, erected on the bank of the river Avon, nearly a mile below Bristol.

Sect. VII. Methods and for Tides, Obser- tions.

of Bunt's

(474.) The principal parts of Mr. Bunt's tide-gauge (figures 34 to 39) are A, an eight-day clock, which turns a vertical cylinder B once in 24 hours; the upper end of B carrying on its circumference a toothed contrate-wheel, in which works a pinion p carried by the axis of one of the clock-wheels. C is a wheel with grooved circumference; to which is attached the wire E, which passes over the upper part of C, (lying in its groove,) and over a large pully F attached to the outside of the quay-wall, and depends in the water-trunk, supporting the float D at its lower end. A counterpoise G is suspended by a wire attached to a smaller barrel carried by the same axis as C, and thus keeps the wire E constantly stretched, and moves the wheel C when, by the rising of the water, the float D ceases to pull upon E. H is a still smaller drum carried by the same axis as C; a finer wire is attached to it and wrapped round it, and on this wire is suspended the bar I which carries the pencil K. The diameters of the drum H and the wheel C are so adjusted that the vertical motion of the pencil is one-eighteenth part of the vertical motion of the surface of the water. a is a strong oak frame attached to the quay-wall; from it project arms cc whose ends are supported by pillars dd; there also projects an arm e whose end is supported by the pillar f. cc carry the mahogany frame b, to which the clock, the bush for the upper pivot of B, and one bearing of the spindle of C, are attached, (the other bearing of the spindle of C being in another upright S;) e carries the bush for the lower pivot of B. The nature of its bearing may be seen in figure 38; it is in a plug b, which may be lowered by a screw and winch, either for adjustment, or for taking the cylinder out, (for mounting papers, &c., upon it;) as by lowering it, first the upper pivot is disengaged, then the lower, and then the end of the cylinder may be made to slide upon the pieces aa.

(475.) The upper end of the bar I slides between two guides P and N, and the lower end between two guides QQ. It carries the small brass bar d (fig. 37), which has movement upon an axis whose projection is at e, (the movement being in the direction to or from the surface of the cylinder, and the axis being sufficiently long to permit no other sensible movement.) The bar d carries the pencil-holder K, which is pressed towards the great barrel by the crooked lever carrying the small weight L. h is a screw for adjusting the height of the pencil-frame in reference to its suspending wire. The great barrel B is 24 inches in length and 48 in circumference; it is made of mahogany staves, screwed upon mahogany ends and diaphragm, and covered with white enamel.

(476.) The action of this machinery will be understood from the remarks in (473.). Referring to the *Philosophical Transactions*, 1838, for some parts which we have omitted, we think the following points important. The pallets (in the escapement of the clock) may be detached from the train, by lifting a latch behind the clock, and drawing them backward; this arrangement is required from its being necessary to fix the hands so that they cannot, as in other clocks, be made to slide without carrying the train along with them. The pinion which drives the cylinder may be detached by pulling it forwards, so as to allow the cylinder to be turned freely. From inequalities in the teeth of the wheels the cylinder is not moved through exactly equal spaces in equal times; to prevent error from this cause, the places of the hours and minutes marked on the top of the large cylinder were thus determined: the pallets were detached from the clock, (the large cylinder remaining connected with it,) and the hands were moved to indicate 0 hours 0 minutes, 0 hours 20 minutes, 0 hours 40 minutes, &c., and at each of these positions a pencil line was drawn on the cylinder by sliding the pencil-frame between its guides. The scale of height was determined by marking feet and inches on the outside of the float-trunk, and noting the internal indication of the gauge as the tide rose to each successive foot on the trunk. A small scale M, carried by the frame b, may be pushed in contact with the barrel, and thus the heights and the times may be read; or lines of feet may be *turned* on the barrel, by causing it to revolve while the pencil is held to it. The float is of pine, well saturated with oil; the aperture by which the water enters is about $\frac{1}{100}$th of the sectional area of the trunk.

(477.) A sheet of paper is wrapped round the cylinder and expanded by moisture; its ends are then pasted together, and it may (if necessary) be fixed with pins or bands. The curves are then well traced by the mechanism upon the paper, and it may be removed at pleasure.

The same sheet may be retained on the tide-gauge during a fortnight.

(478.) If it were desired to take the record of each tide so as to exhibit the course of a great number of tides in sequence, as in fig. 40, it would be necessary to apply a fresh paper every day to the barrel. But remarking that the tide comes later on each successive day by nearly an hour, and that the same hour of high water recurs only in 15 days, it is evident that the same paper may be kept upon the cylinder for a fortnight without risk of the curves interfering, although there may be a great complication of lines on the paper. In figure 41 we give a copy of the curves delineated by the self-registering tide-gauge at Sheerness, (extracted by permission of Captain Beaufort, R. N., Hydrographer,) from 1840, December 23, (new moon,) to 1841, January 7, (full moon.) The reader, in tracing the curves, must conceive the two ends of the drawing to be united, and must begin at the point marked with the word "Change." We have selected this period, because it exhibits one of the greatest irregularities that we have ever known in the tides, namely, that of 3d January, 1841, morning tide, when the water was five feet lower than was expected. This is fully confirmed by observations made at the same time at Woolwich, at Deptford, and at the London and St. Katherine Docks. It followed a very heavy gale which had blown partly from S.W., and partly from N.W. or N. In figure 42 we give a copy of some of the curves traced by the Bristol tide-gauge at the same time, (with which we have been favoured by Mr. Bunt.) In figure 43 are represented a few curves, (corresponding to another period,) traced by the self-registering tide-gauge at Swansea, (for which we are indebted to the kindness of J. W. G. Gutch, Esq.) It must be remarked that the floats of the tide-gauges at Bristol and Swansea do not descend sufficiently low to record the phænomena of low-water; that at Sheerness fully records the circumstances of low water. The reader will at once see that the information furnished by this instrument is infinitely more valuable than could have been obtained by any system of personal observation.

Specimens of the curves traced by self-registering tide-gauges.

Methods of reducing tidal observations

(479.) We shall now proceed with the methods of reducing tide-observations. And first, in regard to the law of rise during each tide at any given locality.

applicable to the course of a single tide at any place.

Although times of high water and of low water have been observed, and their difference of velocities up the same river have been remarked, and although curves exhibiting to the eye the laws of rise and fall have been traced, (by some of the means above described,) we are not aware that they have been reduced to algebraical form except by the writer of this paper in the *Philosophical Transactions*, 1842. The elevation of the water had been observed at Deptford at every quarter of an hour during half a lunation. The spring-tides and those near them were classed together as one group, and the neap-tides and those near them as another group. In order to combine those of each group, it was assumed that the predicted time of high water in the Nautical Almanac was correct, (a constant difference excepted,) and the interval from one predicted high water to the next was conceived to correspond to 360° of *phase*, and the time of every intermediate observation was converted into *phase* by that proportion. (In a subsequent discussion of tides observed every five minutes at Southampton, we have, instead of using any predicted time, fixed upon the estimated times of low water as the origin of phase.) To bring all the observed heights to a comparable state, the range from high water to low water in every half-tide was supposed to correspond to 2·000, and the depression below the nearest high water at every observation was converted into number by that proportion. The various tides in each group were thus made entirely comparable. The means of all the phases and all the converted depressions within every 10° of phase were taken, and thus a series of mean phases very near to 5°, 15°, 25°, &c., and the corresponding converted depressions, were obtained. By observation of the progress of the numbers, it was easy to alter the latter so as to obtain converted depressions corresponding exactly to 5°, 15°, 25°, &c. Then it was assumed that these could be represented by the following formula:—

$$\begin{aligned}\text{Converted depression} = {} & A_0 + A_1 \cos.\,\text{phase} + A_2 \cos.\,2\,\text{phase} + \text{\&c.},\\ & + B_1 \sin.\,\text{phase} + B_2 \sin.\,2\,\text{phase} + \text{\&c.},\end{aligned}$$

which, it is well known, is sufficient for the representation of a function which is periodical for 360° of phase. Then the values of A_0, A_1, B_1, &c., are determined with comparative facility in the following manner. 1st. A_0 is the mean of all the converted depressions. 2nd. Multiply every converted depression by cos. phase, and take their sum; then, (since $\cos 5° + \cos 15° +$ &c. to $355° = 0$; $\cos 5°.\sin 5° + \cos 15°.\sin 15° + \text{\&c.} = 0$; $\cos 5°.\cos 10° + \cos 15°.\cos 30° + \text{\&c.} = 0$; and so for every one except the multiplier of A_1, where $\cos^2 5° + \cos^2 15° +$ &c. to $355° = 18$), that sum $= 18\,A_1$. 3rd. Multiply every converted depression by sin. phase, and take their sum; it will be found to be $= 18\,B_1$. 4th. Multiply every converted depression by cos. 2 phase and take the sum; it $= 18\,A_2$, and so on. Thus the values of all the coefficients are obtained.

Methods of reduction applicable to the laws of height and time at any place in different positions of the sun and moon.

(480.) Secondly, in regard to the laws of time and height of tide at the same place in different positions of the sun and moon. Every examination referring to this object proceeds on the supposition that the times and heights may be represented generally by the forms given by the equilibrium-theory, (45.), (46.), (53.), and (54.), though perhaps with altered proportion of coefficients, arguments altered by addition or subtraction of constants, and (in some cases) altered form of function. Laplace is (so far as we are aware) the first person who combined observations in considerable groups for comparison with theory. His labours will be found in the second and fifth volumes of the *Mécanique Céleste*. In the second volume he treats the observations made at Brest from 1711 to 1716. He commences with the height of syzygial tides. These he divides into four classes, corresponding to the two equinoxes and the two solstices, and uses at least two syzygies (one new and one full moon) for each equinox or solstice, the whole number being 24 syzygies of each class. For each of these he takes the heights for several neighbouring days; and uses, as the whole range of tide on any day, the difference between the mean of two high waters on that day and the intervening low water. In order to determine the interval by which the greatest tide follows the syzygy, he does not remark which tide appears to be the greatest, but he remarks that the tides on the second day before syzygy, and the fifth day after it, are very nearly equal; then, observing the extent of change of tide in one day, (which at those points of the lunation is considerable,) he is able to correct this approximation, and thus to find very exactly the times at which the tides are equal; the time intermediate to these is that at which the total tide is highest. It is found to be almost exactly 36 hours after the syzygy.

Sect. VII. Methods used for observing the Tides, and for reducing the Obs vations.

Laplace's methods treating the heig of the tides.

His methods f the ag of the tide.

For the alteratio of the moon's effect, d pending on her motion right a cension

(481.) Laplace has assumed (without assigning any reason for it except the possibility of a communication between the port of observation and two tidal seas, as in (121.) and (312.)) a result similar to that which we have found in (455.), namely, that the rapidity of the moon's motion in right ascension increases her effect on the tides, as compared with the sun's effect. To discover the value of the coefficient, he proceeds in this manner. Assuming that in the mean of his syzygial tides the moon's declination is sensibly the same as the sun's, the syzygial solstitial tides ought to bear to the syzygial equinoctial tides the proportion of the mean value of the square of the cosine of declination at the solstices to the similar quantity at the equinoxes. Now they are found to be somewhat greater than this proportion gives. The difference is attributed to the moon's quicker motion in right ascension, or slower motion in hour-angle, at the solstitial syzygies than at the equinoxial syzygies; and, assuming the moon's mean effect to be to that of the sun as 3 : 1, or to be $\frac{3}{4}$ of the whole mean effect, the proportional change in the moon's effect caused by that difference of velocities in right ascension is found, and from this the proportional change caused by the whole mean velocity in right ascension is inferred, (supposed to be always proportional to that velocity in right ascension.) From this Laplace finds the moon's effect to be increased $\frac{1}{10}$: this, as we have seen (455.), implies that the sea is 4 miles deep.

For chang parall

(482.) For the effect of the sun's variation of distance, Laplace compares the heights at the winter solstices with those at the summer solstices. For the effect of the moon's variation of distance, Laplace compares 12 apogeal tides with 12 perigeal tides (in syzygies), and finds that their magnitudes are precisely in the proportion given by theory, without any allowance for the difference of the moon's movement in right ascension at perigee and at apogee. (The effect of this, in our theory, will be found in (448.).)

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(483.) The effect of diurnal tide is found on comparing the morning syzygial tides with the evening syzygial tides, at the solstices. In the summer, the evening tides are the greater at Brest; in the winter the morning tides. See (48.) and (63.). But Laplace remarks that observations of low water are necessary for a complete determination, (we shall hereafter find an instance of such a determination.)

(484.) For the quadratures, Laplace first determines the time of smallest tide by a process nearly similar to that for the time of the largest tide near syzygies, and finds exactly the same value for its retardation. In order to determine the proportion of the sun's effect to the moon's effect, by comparing the neap tides with the spring tides, (see (51.) and (52.)) it may be assumed in the mass of observations that the declinations of the two bodies will be equal; but a correction is required, because the inequality in the moon's motion called the *variation* always diminishes her distance and increases her velocity in right ascension at syzygies and produces the opposite effect at quadratures. Making due allowance for this, it is found that a corrected mean spring tide is double a corrected mean neap tide, or that the moon's effect is three times as great as the sun's. On comparing those in which the declinations are remarkably different, the coefficient $\frac{1}{10}$ is again found for the increase of the moon's effect depending on her motion in right ascension. The effect of change of the moon's distance is said to be as distinct in the quadratures as in the syzygies.

(485.) The diurnal tide in the equinoxial quadratures follows the same law as in solstitial syzygies, the moon's declination being the same; but as in the former the sun's declination vanishes, the amount of diurnal tide is only $\frac{3}{4}$ of its amount in the latter. This is verified by the observation.

(486.) To determine the proportions of the effects of the sun and moon from the times of high water, Laplace has taken observations nearly 7 days apart, (nearly $3\frac{1}{2}$ days before and nearly $3\frac{1}{2}$ days after the greatest tides.) For the first of these $2(m-s)$ in (49.) is nearly $-90°$, and for the second it is nearly $+90°$, and therefore these two values give nearly the two greatest possible values for F with opposite signs, and their difference is particularly well adapted to determine the proportion of S' and M'. The effect of the moon is thus also found to be three times that of the sun, or a little greater.

(487.) The hours at which the greatest tides and the least tides occur are determined by interpolating among the times of the observed tides following the syzygies and quadratures. It is found thus that the hour of smallest tide is not quite six hours later than the hour of greatest tide. There are many other deductions compared with theory, but those which we have mentioned are the most important, and they will serve to give the reader an idea of the process which Laplace has followed, using no great number of tides, and not comparing the general laws of particular phænomena, so much as the special values which the expressions assume in extreme cases.

(488.) In the fifth volume of the *Mécanique Céleste*, Laplace has discussed the observations made at Brest during sixteen years, from 1807 to 1822. The theory which he has used is precisely the same as that of his second volume, with this addition, that he has pursued to great length the consequences of his assumption that the effect of each of the attracting bodies, both as regards the coefficient of tide and as regards the constant in the argument, will contain a multiple of the body's angular movement round the earth. In this respect his theory is greatly superior to that of the English philosophers whom we shall mention shortly. The method of expansion which he has adopted is exactly similar to that of (447.) and (450.), though its principles are absolutely arbitrary. We shall defer to the next Section the statement of his results; and shall only mention here that his method of discussion is exactly the same as in his second volume, not using all the observations made at all times, but only comparing those which are made at or near to the times at which the irregularity which he is seeking has its extreme values.

Laplace's method much superior to methods employed before him.

(489.) The method of discussing the observations which we have above described as Laplace's (independently of the advances, however arbitrary their foundations may be considered, in the theory) was undoubtedly a great improvement upon that used by Lalande in his *Traité du Flux et Reflux de la Mer*, who had contented himself with picking out, from the same collection as that first used by Laplace, a single observation here and there, and thus (taking them as affected by winds and other accidents) had sometimes arrived at conclusions opposite to those which Laplace established. But the great principle of employing masses of observations was first used in its greatest extent by Mr. (now Sir J. W.) Lubbock, in the discussion of the observations of high water made at the London Docks during nineteen years (from 1808 to 1826).—See the *Philosophical Transactions*, 1831. The process used by Mr. Lubbock was nearly as follows. The quantity treated in regard to times was, the interval between the moon's passage over the meridian and the time of high water: the quantity treated in regard to heights was, the height of high water above a certain fixed mark on the dock-wall. Then, first, the observations were divided by months, (the observations of every month of January during all the nineteen years being collected into one group, those of every month of February into another group, and so on.) As the moon's node has performed one revolution, and the moon's perigee two revolutions, almost exactly, in the nineteen years, and as the inequalities in the moon's motion not connected with the time of year depend only upon these elements, and have gone through all their changes in the nineteen years, it is plain that the means inferred from these groups will give an accurate representation of all the phænomena which depend solely upon the time of year. The groups were then subdivided into parcels, each parcel including all the observations at which the moon's passage over the meridian occurred in each half hour of apparent solar time. Thus for the month of September, the first parcel included all the observations corresponding to the moon's passage over the meridian within half an hour after the sun for every September through the nineteen years; the second included all in which the moon passed more than half an hour and less than an hour after the sun, and so on. Thus the first table of rough results was obtained, which, when its irregularities were smoothed down, gave a table of results adapted to further use. Secondly, the observations were divided into groups corresponding to minutes of the moon's horizontal parallax, (the first group including all in which the moon's parallax was greater than 54′,

Mr. Lubbock's methods of treating times and heights of high water.

For mean values depending only on the time of the year, and the time of the moon's transit.

For the effect of variation of parallax.

and less than 55′, and so on,) and each group was subdivided into parcels corresponding to each hour of apparent solar time at which the moon passed the meridian; the observations made in the afternoon were, however, alone employed here. Thirdly, the observations were divided into groups corresponding to every three degrees of declination of the moon, (the middle group containing all in which the declination was between $1\frac{1}{2}^\circ$ north and $1\frac{1}{2}^\circ$ south,) and each group was subdivided into parcels corresponding to each hour of apparent time in which the moon passed the meridian. The mean of each parcel was in all cases taken, as well for the times as for the heights. Thus three sets of tables were obtained, the leading division of the first being the month, that of the second being the parallax, that of the third being the declination; and all being subdivided according to time of moon's transit. In the first table, the means of all the results for the different months corresponding to the same half hour of moon's transit were taken. These means were subtracted from all the quantities of the three sets of tables, and thus new tables were formed. Then it was intended by the author that a tide (either in time or in height) should be computed as follows:—1st. The quantity depending on the moon's transit only should be taken. 2nd. The correction to this depending on month and moon's transit should be added. 3rd. The correction depending on parallax and moon's transit should be added. 4th. The correction depending on declination and moon's transit should be added. It was, however, pointed out by Mr. Whewell and acknowledged by Mr. Lubbock (*Philosophical Transactions*, 1834) that the last correction is nearly included in the second, because for a given month and given hour of moon's transit the moon's declination is given, excepting that part which depends on the inclination of her orbit to the ecliptic.

For the effect of variation of declination.

(490.) Observations were also selected in classes, to show that there is no sensible diurnal tide at London; and others showing that the direction of the wind produces no sensible effect. Although little of mathematical deduction accompanied this work, we must allow that it was far more complete as a classified discussion of observations than any that had preceded it.

(491.) In the *Philosophical Transactions*, 1833, Mr. Lubbock applied the same method (merely so far as the process for the first table mentioned above) to observations made at St. Helena, Brest, Plymouth, Portsmouth, and Sheerness. In the volume for 1834 he has modified the tables of 1831, so as to correct the error which we have mentioned. In the volume for 1835 he has discussed an immense number of observations, made at Liverpool during nineteen years from 1774 to 1792. They are treated in exactly the same manner as the London tides, except that the observations when the moon's declination is north are separated from those in which it is south, the difference between these showing the existence of a diurnal tide. In the volume for 1836, the same observations are discussed specially for the discovery of the diurnal tide; the process is simply to divide by months and to subdivide by half hours of transit, (as before,) which defines in every case the moon's declination nearly, and then to divide each parcel once more into two parts, one part including upper transits of the moon with north declination, and lower transits with equal south declination, (the tides corresponding to which ought to be similar,) and the other part including upper transits of the moon with south declination, and lower transits with north declination.

Sect. VI Method used fo observin the Ti and fo reducin the Ob servatio

Mr. Wh well's n thods o treatin Mr. Lu bock's results

(492.) Thus far, however, we have merely numerical values, embodying the result of all the observations in a convenient form, and adapted to prediction, but not giving mathematical laws. The first step to this object was made by Mr. Whewell in the *Philosophical Transactions*, 1834. The following is his method, for the times of high water; it being premised that the parallaxes and declinations spoken of are the same as those used by Mr. Lubbock, and therefore are those which correspond to the time of high water, or a time near it, and not those which correspond to the anterior time indicated by theory in (452.). First, he remarks that (as pointed out by Mr. Lubbock) the mean of all the intervals between the moon's transit and the high water contains a term corresponding very exactly in value for different hours of moon's transit to the first term in (54.) increased by a constant (for London 1 hour 26 minutes), provided we diminish $\overline{m-s}$ by another constant (for London 2 hours); the value of $\frac{S}{M}$ being properly determined $\left(\text{for London it is } \frac{1}{2\cdot 99}\right)$. Next, he takes the tables of difference for each half hour of moon's transit between the mean interval and interval corresponding to different values of the moon's parallax; and, by inspection, he sees that in regard to the changes produced by change of parallax, the numbers in the table change sign when they pass 57′ (the mean parallax); and, in regard to changes of hour of transit, they may be represented by $\sin^2$ (hour of transit—4^h), and therefore that the formula is something like a multiple of $p'.\sin^2$ (hour of transit—4^h). Determining the multiplier so that the sum of all the numbers in the table will be represented by the formula, he obtains finally $3^m \times p' \times \{1+\sin(2.\overline{m-s}-2^h)\}$. This does not correspond exactly to the second term in (54.). For the declination, he changes all Mr. Lubbock's numbers expressing the difference from the mean state depending on declination, to the difference from the numbers when the declination is 0, and shows that in regard to change of declination the sum for all the different hours of transit may be expressed nearly enough by a multiple of the square of the sine of declination, and that when the mean for declination 0 is restored, the mean correction may be expressed by $11-132\times\sin^2$ declination. He then applies this quantity with sign changed to Mr. Lubbock's numbers, and finds that there remains another set of numbers whose law is to be investigated. From inspection, nearly as before, this is found to be represented nearly by

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$$84\left(\frac{1}{12}-\sin^2\text{declination}\right)\sin\left(2.\overline{m-s}-8^h\right);$$

and thus the whole correction for declination is

$$\left(\frac{1}{12}-\sin^2\text{declination}\right)\left\{132+84\sin(2.\overline{m-s}-8^h)\right\}.$$

The observations of height are discussed in a similar manner; the general principle being, to take the principal term of the expression in (53.), and to examine whether the principal part of the height agrees with it, (the correction to $m-s$ being somewhat different from that used for the times of high water.) Then the differences depending on parallax and on declination are resolved into parts nearly in the same manner as above. We shall not delay further on this, but shall remark that, however much the conclusions were modified by later suppositions or by choice of expressions analogous to those of (457.), &c., we confidently refer the reader to this investigation as one of the best specimens of the arrangement of numbers given by observation under a mathematical form. In the *Philosophical Transactions*, 1836, Mr. Whewell has used the same method with some small additions, for reducing to law the numbers given by Mr. Lubbock's discussion of the Liverpool tides.

(493.) In the *Philosophical Transactions*, 1833, Mr. Lubbock exhibited the inequalities of the time of tide, (neglecting those depending on parallax and declination,) by graphical construction, for six different places. The method is, to construct a curve, in which the time of the moon's transit is the abscissa, and the interval from transit to high water is the ordinate. In the same volume, page 232, Mr. Whewell recommended the adoption of this as a general method of obtaining the numbers useful for prediction of tides. In discussing a series of observations made by the persons employed on the Preventive Service, (*Philosophical Transactions*, 1835,) he appears to have used projections extensively. In examining the effect of the sun's declination in the Liverpool tides, graphical projection was used by Mr. Whewell, to exhibit the numbers remaining after the application of other known corrections; and, a curve being drawn with a free hand among the points laid down from the actual numerical data, this curve was treated as the proper representation of those remaining numbers, and the values at different times were measured from the curve, instead of adopting the numbers themselves. Since that time, the use of curves has been commonly adopted by Mr. Whewell and Mr. Lubbock, (see the *Philosophical Transactions* for 1837, and especially the investigation of the progress of the diurnal wave by Mr. Whewell;) and in the *Philosophical Transactions*, 1838, Mr. Whewell (adopting Mr. Bunt's methods) has given rules for the most advantageous employment of the method of curves. They are as follows:

(494.) "Upon a series of parallel ordinates corresponding to the times of moon's transit, I lay down the successive tides, that is, the heights or the lunitidal intervals, as the one or the other are the subject of examination. This curve is more or less irregular, but for most places the leading feature is the zigzag form which arises from the diurnal inequality. A curve is drawn by the eye so as to cut off this inequality, leaving equal differences above and below. We may then proceed as follows to find the other inequalities.

"Having laid down the observed intervals and heights, referring both to the *apparent* time of the moon's transit, and having drawn through each series of points the dotted line which cuts off the diurnal inequality only, but retains every other, I trace off on a piece of transparent paper, having an axis drawn on it extending from 0 hours 0 minutes to 12 hours 0 minutes transit, the successive portions of the dotted line of observation just mentioned, which are included between those hours during the first three months of the year; fitting the tracing paper in its place every time by means of the two extreme points of the axis. I thus obtain six irregular curves, [the same curves, nearly, occurring twice in each lunation,] the mean of which is found by drawing across them, at equal distances, twenty-four vertical lines, and finding by my scale a point in each which is the exact mean of the six intersections. In this manner I get four mean curves [one for each time of three months] on separate pieces of paper, which by repeated combinations are reduced into one, being the mean semimenstrual curve for the year.

"The next step is to reduce this curve to a mean parallax (57′·2) at each hour of transit. For this purpose an arrangement must be made, showing the mean parallax for that year at each of the twelve hours, which will be found to vary from about 56′·9 to 57′·5. [That is, for each of the days throughout the year, at which the moon's transit occurs between 0 hour and 1 hour, the parallax must be taken from the Nautical Almanac, and the mean of all these must be supposed to apply to 0 hour 30 minutes; and so for other hours.] The parallax table of the preceding year, if already discussed, will be sufficiently near for making the requisite small alteration of the curve to the mean parallax; otherwise an approximate parallax table for the current year must be first made.

"I then calculate [in the same manner] the mean declination, [for each hour of the moon's apparent transit,] which varies, not only as the parallax, slightly from hour to hour, but also considerably from year to year. The hourly differences (being only about half a degree from the mean) I have disregarded, and I prefer marking on each annual curve the mean declination of that year, to any attempt to reduce the different annual curves to one common declination.

"Having [as before mentioned] very carefully obtained the mean semimenstrual curve, I cut it out nicely on a piece of thick drawing-paper, and laying the intersections of the vertical hour lines of 0 hour and 12 hours with the axis, on the corresponding points on my sheets, [viz. those mentioned in the first paragraph,] I pencil-in the mean curves, and then ink them. The residue, or space between the mean curve and that of observation, is next transferred to a straight line below [as an ordinate to a new curve.]

"In examining this residue, the first step is to lay on an *approximate* line of parallax. For this I make an arrangement for every hour of transit, and for 54′, 55′, 56′, and 59′, 60′, 61′ of parallax [that is, two groups for each hour] (omitting 57′ and 58′) of all the vertical distances, at the successive hours of transit, of the curve from the straight line, adding to each a constant to avoid negative quantities. I thus obtain twenty-four parcels, the means of which give an approximate correction for 55′ and 60′ at every hour of transit. From this a first line of parallax is laid down, preparatory to the obtaining of the declination-corrections.

"These are obtained by collecting the measured distances from the parallax line to the curve, into parcels of 0° decl. to 13° decl., and 21° decl. to 28° decl. for every hour of transit, omitting those of 14° to 20° decl., and taking the axis, with the mean declination of the year, as a better representative of the mean declinations. The means of these twenty-four parcels give me a declination-correction very near the truth. From this I lay down, on the parallax line, the effect of declination, and thus get an approximate curve of declination combined with parallax. Both this and the former curve of parallax are drawn in with pencil only, being merely used as approximations, whence *corrections* of the first parallax and declination-*corrections* are obtained. This is done by an arrangement (as before) of the spaces still remaining between the pencil curve of declination combined with parallax, for hours of transit and for 54′, 55′, 56′, and 59′, 60′, 61′ parallax, which gives a small additional correction of the parallax corrections first obtained. From this corrected parallax correction, I draw in, with ink, the true parallax line, making the requisite alteration in the line of declination combined with parallax, which is then also inked in. Finally, a *correction* of the declination-corrections being made from this latter line, is considered as giving the true effect of the declinations."

The accuracy of result depends on the assumption of a correct law.

(495.) We have only to remark further on this, that much will depend upon the operator's mental assumption as to the *law* of the inequality as depending on either of the elements of correction. If, for instance, he assumes (as required by theory) that the correction for declination is nearly proportional to the square of the declination, it will be better to use the square of declination throughout. It is evident that there is nothing in the precepts above to prevent the operator from referring the parallax, declination, &c., to any time previous to the transit which immediately precedes the tide; and this, in fact, is done by Mr. Whewell in some discussions of tides.

Comparison of Laplace's methods with Mr. Lubbock's and Mr. Whewell's.

(496.) In remarking on these methods we cannot fail to observe that Mr. Lubbock's method of using *all* the observations for his first results, and the methods founded on this by Mr. Whewell, are in some respects greatly superior to Laplace's, which used only observations made at particular times. Thus Laplace *assumed* that the principal corrections for parallax *must* occur on the days when parallax was greatest or least; Mr. Lubbock's method, if properly used, would show whether that is true or not. On the other hand, Laplace's method is much superior in the facility which it gives for introducing such considerations as that of the variation of effect produced by variation of velocity in right ascension, (a real quantity, as shown by the second terms in our expression of (448.), and by the remarks in (455.), though for a reason very different from Laplace's.) But, viewing the two independent methods introduced by Mr. Whewell, of reducing the tabular numbers to law by a process of mathematical calculation, and of exhibiting the law to the eye without any mathematical operation by the use of curves, we must characterize them as the best specimens of reduction of new observations that we have ever seen; although, with a more accurate knowledge of theory, they might have been much improved.

Methods applying to the progress of the tide-wave across the ocean.

(497.) Thirdly, in regard to the progress of the tide over the different parts of the sea covering the greater portion of the earth. As the tide is itself a changeable state of the water, and as its elements vary from day to day, it is necessary to fix upon some definite phænomenon at some definite time in order to be able to compare the times of tide at different places. By common consent of mariners, the time adopted is "the time of high water on days of new moon and full moon," or rather the interval from the moon's transit at which high water occurs on those days. This is called the *establishment* of a port. It is to be observed that the interval taken on the day of new or full moon is not the same as the mean of all the intervals taken under all circumstances; this latter is termed by Mr. Whewell the *corrected establishment*, and it is by far the more important element in scientific discussion. The former however is most easily understood by practical men, and it is therefore the element most usually adopted in such comparisons as those of which we are speaking.

Establishment; its meaning.

Sect. V. Method used fo observin the Tid and for ducing Observ tions.

(498.) Now the establishment is commonly given in the time of the place. But in order to make the establishments of different places comparable, with the view of tracing the general course of the tide, we must express them all in the time of one standard place, Greenwich for instance. For this purpose we have only to subtract the east longitude or add the west longitude, (expressed in time,) and we have then a set of numbers which are strictly comparable, and which express the Greenwich time of high water at each of the places on the day of new or full moon.

(499.) Suppose now that these last numbers are marked on a chart, and that, on inspecting the chart, we see at two points on opposite sides of a sea and at several small islands between them the same indication III^h. This denotes that it was high water at all those places at the same time, which on a day of new or full moon was 3 o'clock. We may then consider the tide as a great wave whose ridge passed through those places at 3 o'clock on that day. Suppose that, on looking at another part of the same sea, we find a series of points marked IV^h. From this we infer that the ridge of the wave passed through this series of places at 4 o'clock on the same day. We conclude therefore that the ridge of the wave has travelled from one of these lines to the other in one hour; not by the motion of the particles of water through that space, but by the change in the relative motion described in (135.), and other parts of Section IV. If now we draw a line through the first series of points that we have mentioned, it is called the *cotidal line* of III^h; a line drawn through the second series of points is called the *cotidal line* of IV^h; and so on.

Cotid lines.

(500.) Cotidal lines of this kind had been drawn by Dr. Young and other writers, but to a small extent. The first instance (so far as we are aware) in which they were traced on a large scale, was in the charts inserted by Mr. Lubbock in the *Philosophical Transactions*, 1831. But greater extent, as well as greater accuracy, were given by Mr. Whewell's investigations in the *Philosophical Transactions*, 1833, 1835, and 1836.

(501.) It is proper to remark that the whole of our directions regarding this matter go on the supposition that the semidiurnal tide is the only one of any importance; at least that the diurnal tide, though perhaps sensible, does not materially disturb the times and general order of the semidiurnal tide. We shall however find instances in which the diurnal tide is far greater than the semidiurnal tide. In these cases the word *establishment* ceases to be applicable. And though it would not be difficult to extract, from a long series of observations, a fundamental number bearing the same relation to the semidiurnal tide which the ordinary establishment bears to the semidiurnal tide of other places, yet it is not easy so to state a rule that nautical persons would be able speedily to ascertain its value for such a place. In regard to these localities therefore cotidal lines are yet wanting.

(502.) We cannot close this part of our work without remarking on the confusion, and the consequent difficulty of drawing cotidal lines, produced in many places by the inaccurate habits of seamen and all who minister to them, (in England at least,) in not distinguishing between high water and the termination of flood or slack water. On this point see (5.) and (184.). In French works these are carefully distinguished: thus in Romme (*Tableau des Vents et des Marées*) the words *flot* and *jusan* are appropriated to the flow and ebb, while *montant* and *perdant* are used only for the rise and fall; and the want of synchronism between them is clearly explained. But in some of the best English charts, from ignorance of this circumstance, the times of high water on the coast and in the sea at a few miles distance are marked as differing 2½ hours or 3 hours; and even in the table of tides in the *Nautical Almanac*, the establishments at Portland Road and Portland Race are marked as differing 3 hours. We trust that this stain on the scientific character of our mariners will soon be removed.

SECTION VIII.—COMPARISON OF THE PRECEDING THEORIES OF THE TIDES, WITH OBSERVATIONS.

(503.) In the present Section we propose to bring together the principal results obtained by the methods described in the last Section, and to confront them with the theories of the preceding Sections. For convenience we shall divide this Section into the following Subsections:

- Subsection 1.—On the individual tides in rivers, and in bays and estuaries in which the character of the tides is nearly similar to that of rivers.
- Subsection 2.—On the individual tides in some small seas.
- Subsection 3.—On the laws of the tides for varying positions of the Sun and Moon, at several different places.
- Subsection 4.—On the progress of the tide over different parts of the ocean.

Subsection 1.—On the individual Tides in Rivers, and in Bays and Estuaries in which the character of the Tides is nearly similar to that of Rivers.

(504.) The common property which unites the various classes of canals considered here is, that the elevation and depression of the surface of the water bear a sensible proportion to the depth of the water. The theories, therefore, which are to be considered as specially applying to them are, the whole of the Subsection commencing at (192.) and illustrated by figures 9, 10, 11, 12, 13, 14, 15; and the theory from (307.) to (309.), illustrated by figures 16 and 17. Besides these, however, we shall find it necessary to apply the theories relating to variation of breadth and depth (238.) to (264.), because in far the greater number of rivers, &c., the breadth and depth diminish in proceeding from the sea. And in all cases the laws of friction must be supposed to apply, and the theorems from (332.) to (335.) must therefore be used. We shall now advert to special instances.

(505.) The theories from (238.) to (264.) lead us to expect that, where a river contracts rapidly and shoals rapidly, the range of tide will certainly increase. We are not prepared to say that the law which we have laid down in (264.) would apply with extreme accuracy, because the assumptions of very slow contraction and very slow variation of depth on which the process of (262.) is founded might not be safe except the contraction, &c., extended through the length of several waves. Still there is no doubt of the general correctness of the result. But the theorem of (332.) shows, as a consequence of friction, that if the channel be uniform the range will decrease. Combining these, we see that there is a certain rate of contraction with which the range of tide will be stationary: if the river contracts more rapidly, the range will increase from the preponderating effect of contraction: if it contracts less rapidly (and *à fortiori* if it expands), the range will diminish from the preponderating effect of friction. We can easily supply the reader with instances.

Instances of the change of magnitude of tide in passing up a river; first increasing, afterwards decreasing.

In the Thames, the mean range at Sheerness is about 13 feet, at Deptford about 17 feet, at London Bridge about 15 feet, and from this point it diminishes gradually to the weir drawn across the river at Teddington, (a few miles above Richmond,) where it is about 2 feet. A longitudinal section of the river, given by Messrs. G. and J. Rennie in the *Fourth Report of the British Association*, is copied in figure 44, (as far as relates to the tides,) and exhibits clearly to the eye this change of extent of oscillation.

The ranges in different parts of the Severn we have mentioned in (7.).

On approaching the Seine, the mean range is about 13 feet; at Havre it is 20 feet; at Quillebœuf it is about 13 feet; and from this point it decreases rapidly.

At the Cumbray islands, in the Firth of Clyde, the mean range is about 6 feet; at Greenock about 7; at Port Glasgow about 9; at Glasgow about 7; after which it decreases.

In the river St. Lawrence, the range increases from 4 or 5 feet at its mouth to 14 feet at Quebec; after which it dies away.

These instances might be multiplied to any extent, the alteration of range of tide in all contracting rivers following nearly the same laws.

Instances of large tides in interrupted estuaries.

(506.) There is, however, another cause which sometimes operates to increase the tides considerably without any convergence; it is the interruption of the canal, supposed uniform, by a barrier. This case is treated theoretically in (307.) and (333.). From (307.) it appears that, if there is no friction, the high water will occur at the same time in every part of the canal, and its range may become very great at the upper end: the horizontal motion, or tide-current, will be very great at the mouth. In (333.) it appears that, from the introduction of friction, the height will not increase so much; and the time of high water will be later as we ascend the canal. Perhaps the best instance of this case is in the Bay of Fundy. At its entrance the currents are very rapid, but the range is only about 8 feet. But at the head of the bay (where it branches into two shoaly arms) the range of tide sometimes amounts to 60 or 70 feet. The high water is later here than at the entrance of the bay by one hour nearly. In the Gulf of California the tide rises to a great height, though small at its entrance. In like manner, the range of tide in the Wash is about 26 feet, while it is only 6 feet at Yarmouth; and at St. Malo, Avranches, &c., it is nearly 40 feet, while at Cherbourg it is only 15. We consider this last instance analogous to the others, because we imagine that the islands of Jersey, &c., almost effectually prevent the tide from flowing on the eastern side of the bay (in any important degree as regards the supply of water for the bay); and, therefore, the tidal entrance to Avranches is, in reality, one of much less breadth than it at first appears.

(507.) The next circumstance in river-tides which we shall notice is, the relation of the times of slack water (or the turn of the current) to the times of high and low water. In (184.) we have seen that if the river-tide were a wave propagated without friction along a uniform channel of indefinite length, the times of turn of the tide would be exactly intermediate to the times of high and low water, or the cessation of flow would be three hours after high water, and the cessation of ebb would be three hours after low water. But every modifying circumstance which occurs in common rivers brings the cessation of flow nearer to the time of high water, and the cessation of ebb nearer to the time of low water. Thus, in (256.) we find that the shoaling of the bottom produces this effect; in (257.) the contraction of its breadth does the same; in (332.) friction produces a similar effect; and in (335.) it does so in a greater degree if the river is stopped by a barrier: this last effect, however, is small at the mouth of the river. From all these causes combined, the turn of current ought to follow the high and low water at a small interval, especially on advancing near to anything like a barrier in the river. It is notorious among all persons acquainted with river-navigation that this is strictly correct in fact; but we are unable to refer to any numerical values, except for Deptford on the Thames. The mean of a great number of observations (discussed by the author of this Essay in a paper in the *Philosophical Transactions*, 1842) gave, for the interval between high or low water and slack water, 37 to 40 minutes of time.

Instance of small interval between high or low water and stationary water.

(508.) The theoretical circumstance to which we shall next allude is that, in a tidal river affected by a general current towards the sea, and subject to friction, the low water in the upper part may be higher than the high water near the sea (343.). We cannot refer to a better exhibition of the observed fact than that in figure 44; the same thing, however, (we believe,) has been ascertained from accurate levelling along the river Forth.

Instance of low water in river higher than high water in the sea.

(509.) The next theoretical point, and the most difficult, (from the imperfection of limited solutions where the convergence of the series employed is very slow,) is the general law of rise and fall of the water at some distance from the sea, the extent of vertical oscillation of the surface bearing a sensible proportion to the depth of the water. Where there is no barrier across the river, (at least within a great distance of the sea,) and where the oscillation is not *very* great, the theory of (192.) to (221.) will apply. From this we find as follows.

(510.) First, supposing the place not very far from the sea, the principal effect will be, that the rise of the water will occupy a shorter time than the fall (see figure 11); and the inequality will be greater far from the sea than near the sea, and greater at spring-tides than at neap-tides. In illustration of this, we are able to place before the reader figure 45, representing the registered tidal curve at Sheerness on the spring-tide of 1841, February 24, afternoon; figure 46, representing the tidal curve formed from observations of the same tide at Deptford; and figure 47, representing the tide of 1821, July 29, (in nearly similar position of the moon, &c.,) near London Bridge (*Fourth Report of British Association*, page 495). In figure 48 is represented the course of the neap-tide of 1841, March 2, afternoon, at Sheerness; and, in figure 49, that of the same tide at Deptford. All these curves are drawn to the same scale, and illustrate fully the points that we have mentioned. In figures 45, 46, 47, the times of rise and fall are, respectively, at Sheerness 6 h. 5 m. and 5 h. 55 m.; at Deptford 5 h. 0 m. and 7 h. 0 m.; and at London Bridge, 4 h. 48 m. and 7 h. 59 m. (the whole time being accidentally too small in the former and too large in the last). In figures 48 and 49 the times of rise and fall are, at Sheerness, 6 h. 30 m. and 6 h. 30 m.; and at Deptford, 6 h. 0 m. and 6 h. 30 m. At Teddington the times are about 1 h. 15 m. and 11 h. We may also state from Lalande, that the tide at Havre occupies six hours in its rise, but that at Quillebœuf and places above it, it occupies not more than two hours. A better instance is that of the St. Lawrence: at 40 leagues below Quebec, the rise and fall occupy equal times; at six leagues below Quebec, the rise occupies five hours, and the fall seven hours; at 20 leagues above Quebec, the rise occupies three hours, and the fall nine hours.

Instances of the change in the form of the tidal curve in passing up a river.

(511.) Secondly, supposing the place somewhat further from the sea, there will be a sensible check to the descent of the water; there may even be a small rise near the middle of the descent. That such a check does occur in fact will appear from figure 50, which is copied from a diagram given by Mr. Russell in the *Seventh Report of the British Association*, representing the tidal curve on the river Dee, in Cheshire.

(512.) Thirdly, supposing the place still further from the sea, and the tide somewhat larger, so as to make another term in the approximation necessary, it appears, from figure 14, (remarking that the tidal curve for any station may be formed nearly enough by reversing the form of the wave near that station,) that there may be a treble elevation in the course of one tide; and comparing this with figure 15, it appears that this phenomenon may be very conspicuous for spring-tides at the same station at which it cannot be perceived at neap-tides. Now this treble tide does occur in the Forth, where it is known by the name of the Leaky. (Something like it occurs also in the Tay, and probably in the Thames and other long rivers.) It is understood that Mr. Russell has in preparation an elaborate account of observations of the Leaky; as it is not yet published, (a short notice only being given in the *Tenth Report of the British Association*,) we must draw our information from Wright's account in the *Philosophical Transactions* for 1750, page 412. The principal points mentioned are, that the Leaky begins at Queen's Ferry, or a few miles above it, and in neap-tides extends 25 miles up the river above Queen's Ferry, and in spring-tides 19 miles further (three miles above Stirling); that the highest water is not that from the first rise, but that from the second rise. (In this respect it appears to differ from the tide represented in figure 14, in which the first rise is the highest; but it is extremely probable that the consideration of friction and of other impediments might sensibly alter this form.) It is stated, also, that there are no Leakies at full moon, though there are at new moon. We doubt the accuracy of the writer in regard to this point, because the circumstances of sea-tide, which alone could affect the river-tide, (namely, semi-diurnal and diurnal tide,) are the same at new and full moon. On the whole, while we see beyond doubt that the Leaky is a legitimate instance of the application of our theory, (having been observed 90 years before the theory explaining it was formed,) we think it has not yet been described with the accuracy that a phænomenon so remarkable deserves.

(513.) But suppose the tide to be so very large in proportion to the depth of the water that our series of terms in (210.) ceases to be convergent; what shall we conclude to be the form of the tide-wave? Our mathematics here are at fault; and (till the analytical difficulty has been overcome) we must refer to observation. We may state this, then, as the result. As the very large tide progresses, its time of rise becomes shorter, and its time of fall longer; but the descent is not uniform, the greater part of the descent occupying not much more time than the rise, and the last part of the descent being almost imperceptibly slow, which again is succeeded by a very sudden and rapid rise of the next tide. The course up the Severn may be gathered from figures 51, 52, 53. At the lower part of the Bristol Channel the rise and fall, we believe, occupy nearly equal times, (although we are not aware of any careful observations,) and figure 51 may be taken as the representation of the tidal curve there. Figure 52 is a copy of a curve traced by a self-registering tide-gauge erected at Hung Road, (near the confluence of the Avon and the Severn,) for which we are indebted to the kindness of Mr. Bunt. The whole time of rise appears to be four hours at the least. Figure 53 represents the tidal curve at Newnham, drawn generally from our own rough observations. The whole time occupied by the rise ($1\frac{1}{2}$ hour) is accurate. We believe that this may be taken as a type of the tide-wave in rivers where the entering tide is remarkably large.

(514.) Connected with this rapid rise of the tide, in the case of the last article, is the Bore; a phænomenon on which, we believe, some misconception prevails. We believe that the following description of its cause and appearance will be found correct. It is necessary for its formation that there be a very large tide rising with great rapidity (thus, at Newnham, where the water rises 18 feet in an hour and half, the bore is considerable). It is necessary, also, that the channel of the river be bordered with a great extent of flat sands, near to the level of low water. These circumstances hold in the Severn, the Seine, the Amazons, the bays at the head of the Bay of Fundy, (Chignecto Bay and the Bay of Mines,) and other places where the bore is remarkable: the second does not hold in the Thames; and, in consequence, that river has no bore. When the rise of the tide begins, the surface of the water is disturbed in mid-channel, so as to distort reflexion, but the water is not *broken;* it is merely like a common wave. This point (which we state from our own observation) is fully confirmed by De la Condamine's account of the bore in the Amazons, and by the practice, in the Hoogly river, (near Calcutta,) and other places subject to a bore, of rowing boats, &c., into the middle of the channel on the approach of the bore, in order to place them out of danger. But as this rapid rise elevates the surface suddenly above the level of the flat sands, the water immediately rushes over them with great velocity and with a broken front, making a great noise. And this is the whole of the Bore. It is, however, a majestic phænomenon, especially when witnessed from a station which commands the river for several miles above and below, (we may particularly mention Newnham churchyard, on the Severn,) and at an hour when other sounds are stilled. The rise of the water continues, after the Bore has passed, with unabated rapidity, as far as can be seen by general observation, and the tidal current flows rapidly up the river, which is now quite full. At last its rapidity of rise diminishes, and at 90 minutes after the bore, at the place which we have mentioned, it begins to drop, the current still flowing up. About 15 minutes after the beginning of the drop, a singular line of ripple (of which we can give no further explanation) is seen, stretching across the whole river, and moving very slowly downwards. This appears to be the place at which the ascending current and the descending current meet; for, as soon as it has passed, the water is seen to be running slowly downwards, and in a very short time it is running with a speed which is scarcely to be seen under any other circumstances of any river, except, perhaps, some of the largest rapids. The remarkable point attending this last phænomenon is, that the phase of change of current moves *down* the river. In every other instance, the phases, whether of high water, of low water, or of change of current, move upwards; although that of low water (208.) moves upwards much more slowly than that of high water. It would seem here that one of the velocities has actuallly changed its sign.

Instance of Deptford tide expressed by a mathematical law.

(515.) The only instance in which the phænomena of tides in a continuous river have been reduced to mathematical law by such a process as that of (479.) is in the tides of Deptford (*Phil. Trans.* 1842). Referring to (479.) for the process used, it appears that the result expressed the depression of the water for every value of *phase;* the *phase* being an angle increasing by 360° from high water to high water, and the unit in terms of which the depression is expressed being the half oscillation. Thus it was found that at Deptford, when the range of tide was 15 feet 3 inches, putting $p =$ phase $-77°.50'$, the depression of the water below a fixed mark might be represented by

$$13\text{ ft. }10\text{ in.} + 7\text{ ft. }7\cdot5\text{ in.} \times \{0\cdot939 \sin p - 0\cdot066 \sin(2p - 38°.22') - 0\cdot048 \sin(3p - 48°.40') \\ + 0\cdot012 \sin(4p - 97°.2')\}$$

and that when the range of tide was 19 feet 2 inches, putting $p =$ phase $-86°.23'$, the depression of the water below the same mark might be represented by

$$13\text{ ft. }3\text{ in.} + 9\text{ ft. }7\text{ in.} \times \{0\cdot902 \sin p - 0\cdot106 \sin(2p - 19°.11') - 0\cdot069 \sin(3p - 62°.19') \\ + 0\cdot033 \sin(4p - 75°.35')\}.$$

Difficulties in reconciling the observed law with the theoretical law.

The first thing to be remarked is, that the mean level (or the term independent of sines) is higher in the large tides than in the small ones. Probably a part of this arises from the influence of the second term in the expression of (309.); but a part also is produced by the difference of the same kind at the mouth of the river, as it appears in Mr. Lloyd's paper (*Phil. Trans.* 1831) that the mean level at Sheerness is higher in spring tides than in neap tides by 7 inches nearly. The next thing which deserves notice is, that the coefficient of sin $(2p-19^\circ.11')$ is larger than that of sin $(2p-38^\circ.22')$ in a greater proportion than that of the range of tides; whereas the expressions of (210.) and (309.), supposing them to be put under brackets with the coefficient of the first term as a general multiplier, would give for the coefficient of the term depending on $2mvt$ a quantity proportional to the range. This seems to show merely that the approximation is not carried far enough for such a tide as that of the Thames. The third point to be noticed is, that the argument of the second term (or the angle whose sine enters into the second term) is not double the argument of the first term, as it ought to be by the expression of (200.) or (210.), but is double the argument of the first term diminished by a constant. This may arise from the same imperfection of the mathematics; or it may be explained thus. The bridges and other impediments may produce in some degree the effect of a barrier, and therefore the true expression ought to be intermediate to those of (200.) and (309.). The former with changed sign, and putting C for bk, gives for the variable part of depression

Explained in some degree by the impediments to the free motion of the water.

$$C\left\{\sin(mvt-mx')-\frac{3}{4}b.mx'.\sin(2mvt-2mx')\right\}.$$

The latter, with changed sign, making $\frac{A}{\cos ma}.\cos\overline{ma-mx'}=C=bk$, and putting $B=180^\circ$, gives for the variable part of depression

$$C\left\{\sin mvt-\frac{3}{4}b.mx'.\tan(ma-mx').\cos 2mvt\right\}.$$

If then the true expression were the mean of these two, it would be

$$C\left\{\cos\frac{mx'}{2}.\sin\overline{mvt-\frac{mx'}{2}}-\frac{3}{8}b.mx'.(\cos 2mx'.\sin 2mvt-\overline{\sin 2mx'-\tan(ma-mx')\cos 2mvt})\right\}.$$

If $\frac{\sin 2mx'-\tan(ma-mx')}{\cos 2mx'}=\tan\overline{2mx'-D}$, where D will be small if the place of observation is near to the bridges, &c., this will become

$$C\left\{\cos\frac{mx}{2}.\sin\overline{mvt-\frac{mx'}{2}}-E.\sin\overline{2mvt-2mx'+D}\right\};$$

and if we put $\overline{mvt-\frac{mx'}{2}}=p$, it becomes

$$C\left\{\cos\frac{mx'}{2}.\sin p-E.\sin\overline{2p-mx'+D}\right\}$$

or

$$C\left\{\cos\frac{mx'}{2}.\sin p-E.\sin\overline{2p-F}\right\},$$

an expression possessing the peculiarity in the form of the argument of the second term to which we have adverted. On the whole, we regard the phænomena of the Deptford tides as agreeing pretty well with the laws given by our mathematical investigations.

Instance of a river (the Amazons) with several high and low tides existing upon it at once.

(516.) Before quitting the subject of tides in continuous rivers we may remark, that it is easy to conceive a river so long that there may be at the same instant several tides of high and low water alternately at different points along the river, its course being so long that the wave of high water occupies several days in passing up. We are aware of only one instance in which this is recorded as actually having been observed, namely the river Amazons. De la Condamine, who descended this river in 1743, (see the French *Memoirs* for 1745,) has stated that the tide is observable at Pauxis, 200 leagues from the mouth of the river, and that between this place and the mouth there are at any instant a score of places, more or less, [*une vingtaine de parages, plus ou moins,*] at which it is high water at that instant; the places intermediate to these having low water at those times. He conceives the tide-wave to advance there at the rate of one league per hour nearly.

Instance of estuary tide (Southampton) reduced to mathematical law. Difficulty of explaining it.

(517.) When the river is stopped by a sudden barrier, (a circumstance which holds nearly in the Southampton Water, the Orwell, the Stour, several arms of the sea on the coast of Cornwall, many of the sea-lochs of Scotland, &c., and many other estuaries,) the theory of (309.) illustrated by figures 16 and 17 ought to apply. We are not aware that sufficient observations have been made upon any estuary-tide except that of Southampton, and there they give the very singular curve represented in figure 54. Here is a double high water, as in figure 17, and it appears therefore that there is some agreement between the theoretical and the observed forms. But this is not so obvious when the height is expressed algebraically by the process of (479.). It appears, then, that the variable part of the depression below a fixed point (as applying to seven tides between 24th February and 27th February, 1842) may be expressed by

$$7\text{ ft. }3\text{ in.}\times\{0\cdot 898.\sin p+0\cdot 194\sin\overline{2p-1^\circ}+0\cdot 191\sin\overline{3p-68^\circ.8'}+0\cdot 034\sin\overline{4p+5^\circ.43'}\}$$

where p is an angle increasing uniformly with the time, and changing through 360° in the course of one tide. The theoretical expression (309.), as modified in (515.) is

$$C\times\left\{\sin mvt-\frac{3}{4}b.mx'.\tan(ma-mx').\cos 2mvt\right\}.$$

This matter is open to further investigation.

(518.) The phænomenon of long continued high water or double high water in estuaries is, we believe, not uncommon. Thus at Havre, as described by Dicquemare, (*Journal de Physique*, 1779,) there is a long continued elevation called *la tenue du plein*. The tidal curve, as far as we have been able to construct it from Dicquemare's description, is given in figure 55. On the coast of Holland, (which possesses all the properties of an estuary in this respect, that the tidal water runs for a great distance over a shoaly bottom and then is suddenly stopped by the coast,) there is a double high water (see Moll, *Nieuwe Verhandelingen der eerste classe ... van het instituut ... te Amsterdam, zevende deel*). The first high water appears to be considered by the Dutch, in common language, as the real high water, and the second is called the *agger*, but so little difference is there between them, that, in making the extensive series of simultaneous tide-observations proposed by Mr. Whewell, the agger was sometimes observed for high water.

(519.) We may here properly advert to the anomaly which has been observed in the tides at Christchurch, Poole, and Weymouth, and which by some writers (and by nautical persons on the coast in general) is ascribed to the effect of a tidal current from the Solent or western channel behind the Isle of Wight. We shall first state, that we conceive this explanation to be untenable. Without laying stress on the algebraic circumstance, that the union of two separate tides, one of the form $a.\sin\overline{nt+A}$, and the other of the form $b.\sin\overline{nt+B}$, will produce a simple tide of the form $c.\sin\overline{nt+C}$, it will be seen from figure 56 that the line of the mainland is continued by a long projecting shoal from the visible mouth of the Solent, so as in reality to prolong that channel to a length which, by discharging its water at once into the open sea, must effectually prevent it from affecting a long line of coast. Now in figures 57, 58, 59, we give the tidal curves of these places; in which the part marked with a strong line has been carefully observed by ourselves, (by noting the height of the water every five or ten minutes,) and the rest has been supplied from the information of persons on the spot. It is quite evident, on comparison with figures 12, 52, 53, that these are simply the tides produced by running over a shallow bottom; that at Weymouth corresponding to a case in which the tide is greater than at Christchurch and Poole; which is correct, the tide at Weymouth being double that at Christchurch and Poole. The two latter tides were observed at the mouth of the Avon and at the quay at Poole, and in each of these places the tide has flowed over a shoal, (Christchurch Bay being very shallow,) and has still a considerable distance to flow over it; so that they may be regarded as tides in continued shallow channels. With regard to the Weymouth tide, we cannot explain fully the length of the shoal; but it is remarkable that the cotidal lines follow in close sequence near to Weymouth, which implies that the tide-wave travels slowly *in the same manner* as if the water were shallow, whether that be or be not the cause of it. It would be a curious circumstance if it should be found, theoretically or experimentally, that the alteration of the cotidal lines by the form of the coast produces the same modification of the tides as a shoal which retards the velocity to the same degree. In all three instances also the form of the coast compels the tide to turn backward to these parts, (by passing round Portland Bill to Weymouth, round St. Alban's Head to Poole, and round the reef projecting from Hengstbury Head to Christchurch;) it would be a curious circumstance if it should be found that this assists to produce that modification.

Tidal curves at Liverpool, Portsmouth, Plymouth.

(520.) In the *Philosophical Transactions*, 1840, Mr. Whewell has given tidal curves for Liverpool, determined by observations every half hour and also by observing the exact time at which the surface of the water passed two fixed marks; and tidal curves determined from observations of high water and the time of passing two fixed marks at Plymouth. He remarks that, at Liverpool, the rise occupies less time than the fall; but his tables and his curves imply the contrary for Plymouth. This however is an error, arising from an error in the tabular arrangement of his figures (see page 264, January 4, where the figures 3.28.0 in the last column are improperly raised). On correcting this, it is found that the rise occupies less time than the fall, as, theoretically, it ought to do (204.). And this is the general rule. The tide-observations published by the Admiralty seem to show that at Portsmouth the rise is the longer; but we have good authority for saying that the observations of low water there are very uncertain. It is not impossible, however, that Portsmouth may share in some degree in the peculiarities of Southampton.

Subsection 2.—On the Individual Tides in some Small Seas.

Small tides in the Mediterranean.

(521.) The small information that we possess with regard to the tides of the Mediterranean Sea may be first mentioned. It is notorious that the tides are so small that they cannot usually be recognized; or cannot be distinguished from the effects of wind, (except in the neighbourhood of the Strait of Gibraltar, where they are affected by the tide of the Atlantic Ocean.) This agrees with the result of (300.), in which the greatest value of Y for a closed canal contains as a factor the length of the canal, which for the Mediterranean (considered with reference to tidal phænomena) is small. Yet that there is a tide in every part is shown by the observations of Toaldo at Venice (*Phil. Trans.* 1777). The spring tide there is about four feet, although at the mouth of the Adriatic it can hardly be recognized. It is plain that this case is similar to that of (307.), or to those of the Bay of Fundy, &c., mentioned in (506.), and that a tide, insensible at the mouth, has by virtue of the factor $\frac{1}{\cos ma}$ become sensible at the head.

Tides in the Adriatic Sea.

(522.) The tides in the English Channel claim notice, Tides in the English Channel. False notions on the meeting of tides.

as having been the subject of careful examination by many persons, English and French. A paper in the *Phil. Trans.* 1819, by Captain Anderson, deserves to be mentioned. This writer conceives, that if there is any where a *meeting* of two tides, as from the English Channel and from the North Sea, there must be a terrible disturbance of waters, as if two streams ran to abut each against the other. The reader who has entered into the Theory of Waves will at once perceive that no such consequence follows. While calling to mind the analogy of two ordinary waves on water running in opposite directions and crossing each other without any shock, he may also refer to the result of the investigation in (310.), which is precisely that of two tides from two tidal seas meeting in the same canal, and which shows that at every point the motion of the water is similar to that in ordinary tides, except that there is no simple relation between the times of high water and slack water. If the consideration of friction were introduced, the general expression of (321.), making $H=0$, must be applied, and the same limiting conditions must be used as in (310.), which will show that at both entrances the tide-waves travel towards the centre (except one is much greater than the other). But, dismissing this writer's speculations, we find his information valuable. It appears that in the upper part of the Channel (to which his detailed remarks are confined) the water flows up the Channel nearly three hours after high water, and runs down nearly three hours after low water. He mentions this as a most singular and astonishing fact, although it is merely the law of (184.), which is that of the simplest case of waves. We may mention here, that this continuance of the current after high water, &c., if it last three hours, is called by sailors *tide-and-half-tide;* if it last one hour and a half, it is called *tide-and-quarter-tide*, &c.

Reversion and revolution of currents in the English Channel.

(523.) The results of far more extensive observations are collected by Monnier, in his *Mémoire sur les Courants de la Manche, &c.* From these it appears, as a universal rule throughout the English Channel, that at any great distance from either shore the current runs up the Channel nearly three hours after high water, and down the Channel nearly three hours after low water; and that on the English side of the Channel, especially opposite the entrances of bays, the directions of the currents turn in 12 hours in the same direction as the hands of a watch; and that on the French side they turn in the opposite direction. This is entirely in conformity with the theories of (184.) and (363.). The same laws are recognized as holding in the British Channel, and in the German or North Sea near the Scotch and English coasts. Two instances are mentioned, (off the Start Point and off Ushant,) in which it seems that the direction of the tide, after having turned through a certain angle, turns back through the same directions; but they do not appear to be well established.

Different height of tides in different parts of the Irish Channel.

(524.) With regard to the Irish Channel, we have little to remark, except that there is a very great difference in the height of the tide on the different sides, the tide on the east side being considerably the greater. They are also greater in the northern part (north of Wicklow, on one side, and of Bardsey Island on the other side) than in the southern part. Between Wexford and Wicklow they are very small. For these facts, and for information regarding the height of the tides along a considerable extent of coast, we would refer to fig. 60, (*Chart of British Isles and North Sea,*) in which the small figures along different parts of the coast denote the extreme range of the tide in yards (Whewell, *Phil. Trans.* 1836). The theory of the motion of waves on a large surface of water bounded by an irregular figure is so imperfect that we cannot explain this mathematically; although it seems likely enough that the great wave coming from the Atlantic and passing the south-eastern coast of Ireland should not produce a great rise on its eastern coast. The greater rise in the north is undoubtedly due to the similarity to estuary tides, for which we have had to refer so frequently to (307.) and (333.).

(525.) The tides of the German Sea present a very remarkable peculiarity. Along the eastern coast of England, as far as the mouth of the Thames, the tide-wave, coming from the Atlantic round the Orkney Islands, flows towards the south. Thus, on a certain day, it is high water in the Murray Firth at 11 o'clock, at Berwick at 2 o'clock, at Flamborough Head at 5 o'clock, and so on (see the cotidal lines in figure 60) to the entrance of the Thames. But on the Belgian and Dutch coasts immediately opposite, the tide-wave flows from the south towards the north. Thus, on the day that we have supposed, it will be high water off the Thames at 11 o'clock, (the tide having travelled in 12 hours from the Murray Firth,) and at Calais nearly at the same time: but at Ostend it will be at 12, off the Hague at 2, off the Helder at 6, and so on. This circumstance is so strange, that Mr. Whewell, in order to explain it, has had recourse to the supposition of a revolving tide in the German Ocean, in which the tide-wave would run as on the circumference of a wheel, the line of high water at any instant being in the position of a spoke of the wheel. Although our mathematical acquaintance with the motion of extended waters is small, we have little hesitation in pronouncing this to be impossible. The only conceivable case in which it could hold would be, when there was a shoal in the middle nearly touching the surface of the water: a supposition which does not apply here, the sea between Suffolk and Belgium being somewhat deepest in the middle.

(526.) We believe that a complete explanation may be found in the arrangement of the great shoals of the North Sea. It must be remarked that (except within a very small distance of Norway) the North Sea is considerably deeper on the English side than on the German side; so much so that the tide-wave coming from the north runs into a deep bay of deep water, bounded on the west side by the Scotch and English coasts as far as Newcastle, and on the east side by the great Dogger Bank. As far as the latitude of Hull, the English side is still the deep one: and though a species of channel through the shoal there allows an opening to the east, yet immediately on the south of it is the Wells Bank, which again contracts the deep channel to the English side. After this (that is, in the latitude of Yarmouth) the deep channel expands equally to both sides. It seems reasonable to conclude from this that the great set of north tide is on the English side of the North Sea, both between the Dogger Bank and England and between the Wells Bank and England, (a branch stream of tide having been given off to the east between these two banks:) and that any passage of tide-wave over these banks may be neglected. Now this view is supported in a remarkable degree by the tidal observations on two dangerous shoals called the

Ower and Leman, lying between Cromer and the Wells Bank, but nearer to the latter. It appears that, on these shoals, the direction of the tide-current revolves in the same manner as the hands of a watch. (See Norie's or any other charts, or Monnier, p. 23.) Now, in conformity with the remarks in (363.), this proves beyond doubt that the Ower and Leman are on the left hand of the main stream of tide, (supposing the face turned in the direction in which the tide proceeds,) or are on its eastern border; and therefore that the central stream is still nearer to the coast of Norfolk. From a point not far south of this we may suppose the tide to diverge in a fan-shaped form over the uniformly-deep Belgian sea. Along the English coast, the wave will flow to the south: but it will reach the whole of the Belgian and Dutch coast at the same instant: and, if this tide alone existed, we doubt not that the time of high water would be sensibly the same along the whole of that coast.

(527.) But there is another tide of great magnitude, namely, that which comes from the English Channel through the Straits of Dover. This also diverges, we conceive, in a fan-form, affecting the whole Belgian sea: the western part turns into the estuary of the Thames: the eastern part runs along the Dutch coast, producing, at successive times, high water (even as combined with the North Sea tide) along successive points of that coast from Calais towards the Helder. And this we believe to be the complete explanation of the apparently opposite tide currents. The branch tide of the North Sea running between the Dogger Bank and the Wells Bank will assist in propagating the tide along the German coast from the Helder towards the mouth of the Elbe. We have gone into some detail in this explanation for the purpose of showing the importance of considering the form of the bottom in explanations of specific tides.

(528.) A remarkable set of observations was made by the late Captain Hewett, R.N., on the depth and motion of the water at a strictly definite point (a boat being moored over a small hillock discovered in the bottom of the sea) in latitude 52° 27′ 30″ N., longitude 3° 14′ 30″ E., or a few miles south of the Wells Bank, near the middle of the Belgian sea. They have since been communicated to the British Association. The result was, that the change of elevation of the surface was insensible: but that there was a considerable stream of tide alternately N.E. and S.W. (magnetic). The point in question corresponds pretty well to the intersection of the cotidal lines of 9 o'clock of the North Sea tide, and 3 o'clock of the English Channel tide (ordinary establishment), and these tides would therefore wholly or partially destroy each other as regards elevation. As regards the compound tide-stream, the greatest positive current from one tide will be combined with the greatest negative current of the other, and this will produce a stream whose direction agrees well with Captain Hewett's. At 3^h on the day of new moon, the North Sea tide would be running north (magnetic), and the English Channel tide would be running east, and therefore the compound current would be running north-east; at 9^h it would be running south-west. Both currents, and consequently the compound current, would cease at about 0^h, 6^h, &c., on the day of new moon: and as Captain Hewett's observations were made rather more than a day before new moon, the slack water would occur an hour or more before noon. The whole of this also agrees well with the observation.

Tides and Waves.

Races—Portland Race.

(529.) The phænomenon known by the term *Race* is peculiar to promontories projecting into narrow channels. Thus nearly every headland of the English and Irish channels has more or less of a race. The most remarkable of these is Portland Race. When the rising tide in the neighbourhood is nearly at its mean level, the water begins to run eastward past Portland Bill and over the sunk ledge which projects from the Bill: when the tide has reached its greatest height, the Race is raging most furiously, the velocity of the current to the east being 6 or 7 miles per hour. When the water has dropped to its mean level nearly, the current turns, and at the time of low water it is raging towards the west. It is plain that this current is only the ordinary tide-current treated in (184.), but it necessarily runs past the promontory with great rapidity in order to transfer the proper quantity of water from the bay on one side of the promontory to the bay on the other side.

Rapid currents from bays communicating with tidal seas by two channels.

(530.) It is scarcely necessary to mention at length the rapid currents which are sometimes produced in the channels communicating from a surface of water to two tidal seas, or to two parts of the same sea in which the hours of high water are different. The more rapid current is always that which passes through the narrower channel. Thus, the mouth of the Southampton water communicates with the English Channel by two courses, namely, by the east and by the west of the Isle of Wight: the former, being wide and deep, allows the water to take nearly the same level as that at the east end of the island, and this at some states of the tide is different from that at the west end of the island, and therefore the water runs with considerable velocity in the western channel (the Solent). A more remarkable instance is that of Loch Alsh, on the west coast of Scotland, opposite the Isle of Skye: this island very much interrupts the great tidal channel between Scotland and the Long Island (Lewis, Harris, &c.), and the times of high water on the north and south coasts of Skye are therefore different: Loch Alsh is principally supplied from the north side by the broad entrance called Kyle Haken, and its water therefore nearly takes the level of the northern sea: its height is therefore at some stages of the tide considerably different from that of the southern sea, with which it communicates by the narrow strait of Kyle Rhea; and the water consequently rushes through Kyle Rhea with a current of fearful rapidity, changing its direction twice in every tide.

Mean level of the sea nearly independent of the range of tide.

(531.) We shall close this subsection by stating that, at the expense of the British Association (see their 8th *Report*), a series of levels was carried across the land from Portishead on the Bristol Channel to Axmouth on the English Channel, by Mr. Bunt, and simultaneous observations of the tides were made at these stations, and were referred to the marks whose difference of level was obtained. Although the whole tide at Portishead was 35½ feet, and that at Axmouth only 10 feet, the mean level at Portishead was only 9 inches higher than that at Axmouth: its high water being 13 feet 7 inches higher, and its low water being 12 feet 2 inches lower. Thus it appears that the Theory of Waves, in the manner in which we have throughout used it, considering the greatest elevation above the mean level, and the greatest depression below it, as very nearly equal, is properly applicable to the tides. We have also been informed that the levellings in the Ordnance Survey have shown that the high water in the upper part of the Bristol Channel is higher than at its mouth, and the low water in the upper part lower than at its mouth, by nearly equal quantities: but we possess no documentary information on this point.

Subsection 3.—On the Laws of the Tides for varying Positions of the Sun and Moon.

(532.) The Equilibrium-Theory (44.), Laplace's Theory (98.), (101.), and (107.), and the Theory of Waves (436.) and (283.), (439.) and (441), modified in (448.) and (452.), agree in the general form of the expressions for the elevation of the sea, supposing the coefficients altered and the arguments of the angles altered. We shall therefore (for convenience), in the first instance, use the formulæ of the Equilibrium-Theory in our comparisons, introducing the modifications given by the other theories as may appear necessary.

Dependence of the mean level of the sea on the Moon's declination.

(533.) The first line in the expression of (44.), with which (436.) agrees, gives us the slowly varying effect of the two attracting bodies, in feet,

$$(1{\cdot}34 \times \sin^2 \mu + 0{\cdot}61 \times \sin^2 \sigma) \times (\cos 2 .\ \text{terrestrial latitude} + \mathrm{C}),$$

μ and σ being the declinations of the Moon and the Sun.

In the expression of (44.) C is $\frac{1}{3}$: in that of (436) it is 0. The constant, in both cases, depends on the condition of giving a certain external form to a certain quantity of fluid; the form is the same in both, but the different proportions of the polar to the equatorial surface in the two suppositions (one, of the earth completely covered with water, the other, of a canal passing through the poles) give different absolute elevations. In either case, however, the elevation at mean latitudes is small; it will be most conspicuous near the equator or near the poles. The quantity of information which we have bearing upon this point is small. In the *Phil. Trans.*, 1839, p. 157, Mr. Whewell shows that the observations of high and low water at Plymouth give a mean height of water increasing as the Moon's declination increases, and amounting to three inches when the Moon's declination is 25°. This is in the same direction as that corresponding in the expressions above to a high latitude. The effect of the Sun's declination is not investigated from the observations. In the *Phil. Trans.*, 1840, p. 163, Mr. Whewell has given the observations of some most extraordinary tides at Petropaulofsk in Kamschatka, and at Novo-Arkhangelsk in the island of Sitkhi on the west coast of North America. From the curves in the *Phil. Trans.*, as well as from the remaining curves relating to the same places (which, by Mr. Whewell's kindness, we have inspected), there appears to be no doubt that the mean level of the water at Petropaulofsk and Novo-Arkhangelsk rises as the Moon's declination increases. We have no further information on this point.

(534.) The third line of (44.), which we shall next treat, gives the expression for the ordinary semidiurnal tide, on the Equilibrium-Theory: the corresponding term for one body on Laplace's Theory will be found in (108.); and that on the Wave-Theory for the general combined effect of two bodies, in (457.) and the preceding articles. It appears that the forms of (53.) and (54.), with extensive changes of angles, &c., may be adopted as representing any theory. We shall consider the different parts of these formulæ separately.

Theoretical formulæ for semimenstrual inequalities.

(535.) *Semimenstrual inequality of time and of height.*—This is the name given by Mr. Whewell to the variation of that term, in the expression for the time of high water, or for the height of high water, which in (489.) is called the quantity depending on the Moon's time of transit only; and which, for the time, putting θ for the Moon's hour angle to the west of the meridian at high water, is represented in the first line of the last expression of (54.) by

$$2\theta = -\frac{720^{m}}{\pi} \cdot \frac{\mathrm{S}' .\ \sin 2 . \overline{m-s}}{\mathrm{M}' + \mathrm{S}' .\ \cos 2 . \overline{m-s}},$$

or more correctly by

$$\tan 2\theta = -\frac{\mathrm{S}' .\ \sin 2 . \overline{m-s}}{\mathrm{M}' + \mathrm{S}' .\ \cos 2 . \overline{m-s}} = -\frac{\mathrm{S}_{\blacktriangle} .\ \sin 2 . \overline{m-s}}{\mathrm{M}_{\blacktriangle} + \mathrm{S}_{\blacktriangle} .\ \cos 2 . \overline{m-s}},$$

(see (56.)): and for the height, by the first term in the expression of (53.), which is proportional to

$$\sqrt{\{\mathrm{M}_{\blacktriangle}{}^2 + 2\mathrm{M}_{\blacktriangle}\,\mathrm{S}_{\blacktriangle} . \cos 2 . \overline{m-s} + \mathrm{S}_{\blacktriangle}{}^2\}}.$$

The expressions of (457.), and the articles preceding it, show that, on the wave-theory, these expressions will be changed to

$$\tan (2\theta - 2\lambda) = -\frac{\mathrm{S}'' .\ \sin (2 . \overline{m-s} - 2\alpha)}{\mathrm{M}'' + \mathrm{S}'' .\ \cos (2 . \overline{m-s} - 2\alpha)}.$$

$$\text{Height} \quad \propto \sqrt{\{\mathrm{M}'''^2 + 2\mathrm{M}'''\,\mathrm{S}''' . \cos (2 . \overline{m-s} - 2\alpha) + \mathrm{S}'''^2\}}$$

where the proportion of S'' to M'', or S''' to M''' is not the same as on the equilibrium-theory, in consequence of the relation of the magnitude of the effect to the periodic time of the forces (455.). In considering the mean of many observations in all relative positions of the Sun, the Moon, the perigee, and the equinox, the variable term

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T in (457.) may be neglected. Now the points which we shall examine are, 1st, whether consistent values of $\frac{S''}{M''}$ can be found; 2nd, whether consistent values of α can be found; 3rd, whether, with adopted values of $\frac{S''}{M''}$ and α, the general forms of the observed results agree with those of the formulæ.

Methods of determining the proportion of solar and lunar effects.

(536.) 1st. On the value of $\frac{S''}{M''}$. For the times this may be found by choosing one mean of observations in which $m-s-\alpha$ is as near as possible to 3^h (say 3^h+x) and choosing another mean of observations in which it differs 6^h from the former (or is 9^h+x). These will be respectively the times when the Moon's transit (in solar time) is later by 3^h and by 9^h (nearly) than the time when the tide is greatest. For the first of these, $\tan(2\theta_1-2\lambda)=-\frac{S''.\cos 2x}{M''-S''.\sin 2x}$: for the second, $\tan(2\theta_2-2\lambda)=+\frac{S''.\cos 2x}{M''+S''.\sin 2x}$: and half the difference of these, when x is small, will not differ sensibly from $\tan(\theta_2-\theta_1)=\frac{S''}{M''}$. Or it may be found by taking the least and greatest values of $\theta-\lambda$: for the first of these, $\sin(2\theta_3-2\lambda)=-\frac{S''}{M''}$: for the second, $\sin(2\theta_4-2\lambda)=+\frac{S''}{M''}$: taking half the difference, $\sin(\theta_4-\theta_3)=\frac{S''}{M''}$.

For the heights, the easiest way is to take the greatest and least ranges, which correspond to $M'''+S'''$ and $M'''-S'''$ in the formula, from which the value of $\frac{S'''}{M'''}$ is found.

Different determinations of this proportion

(537.) Thus the following results have been obtained:

At Brest, by all the observations near to 128 syzygies and 128 quadratures (*Méc. Cél.* liv. xiii. p. 204.), from heights, $\frac{S'''}{M'''}=\frac{1\cdot643}{4\cdot755}=0\cdot3456$.[*] There is no deduction from the times, except that made by Mr. Lubbock (*Phil. Trans.*, 1832) from a year's observations, which gives $\frac{S''}{M''}=0\cdot33945$.

At London, by 19 years' observations, from times (Lubbock, *Phil. Trans.*, 1831), $\frac{S''}{M''}=0\cdot37887$,[†] or from another discussion (Lubbock, *Phil. Trans.*, 1836) 0·38386. There is no satisfactory determination from heights, the whole range not having been observed: but supposing the mean range to be 15 feet, and the greatest difference in the height of high water at spring tides and neap tides to be 3·4 feet as shown by Mr. Lubbock's observations, and supposing that (as in the open sea) the variations between spring tides and neap tides are the same for low water as for high water (which does not agree with the observations at Plymouth, where the variation for low water is the greater in the proportion of 3 : 2), the value of $\frac{S'''}{M'''}$ would be $\frac{1\cdot7}{7\cdot5}=0\cdot2267$. This result is worthless.

At Liverpool, by 19 years' observations, from times (Whewell, *Phil. Trans.*, 1836), $\frac{S''}{M''}=0\cdot37866$, or (Lubbock, *Phil. Trans.*, 1837) $=0\cdot37124$. From heights, (Whewell, *Phil. Trans*, 1836,) $\frac{S'''}{M'''}=0\cdot39875$; but as there were no observations of low water, this result is valueless. If the mean range were considered $=24$ feet, and the difference of high water for springs and neaps $=5\cdot48$, $\frac{S'''}{M'''}$ computed as for London $=0\cdot228$. This is worthless.

These determinations (omitting those to which we have taken exceptions) may be considered as first-rate. The following are greatly inferior:

From times only (Lubbock, *Phil. Trans.*, 1833, page 20; and Whewell, *Phil. Trans.*, 1834, page 20).

At Sheerness, from 12 months' observations . . . . $\frac{S''}{M''}=0\cdot37865$

At Portsmouth, 12 months' . . . . $=0\cdot34611$

At Plymouth, 9 months' . . . . $=0\cdot40673$

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[*] Mr. Whewell (*Phil. Trans.*, 1834, p. 20) has quoted as Laplace's value $\frac{1}{2\cdot6157}=0\cdot38231$. We know not on what authority this is given; it is certainly not on that of the *Mécanique Céleste*.

[†] Mr. Whewell has given the number $\frac{1}{2\cdot9884}=0\cdot3346$: we know not on what authority.

From times (Whewell, *Phil. Trans.*, 1838, page 245).

At Plymouth, from 4 years' observations . . . . $\frac{S''}{M''} = 0{\cdot}4025$

At Bristol, 4 years' . . . . $= 0{\cdot}394$

At Leith, Portsmouth, Pembroke, and Ramsgate, (periods not mentioned), $\frac{S''}{M''}$ appears a little less than at Liverpool.

From heights, at Portsmouth $\frac{S''}{M''} = 0{\cdot}2$; at Plymouth $= 0{\cdot}294$; at Bristol $= 0{\cdot}303$.

From heights at Plymouth (Whewell, *Phil. Trans.*, 1839, page 153, &c.), by 6 years' observations of high and low water . . . . $\frac{S''}{M''} = \frac{43{\cdot}5}{144} = 0{\cdot}3021$

At Dundee (page 157), by one year's observation of high and low water, from times . . . . $\frac{S''}{M''} = 0{\cdot}3584$

From heights . . . . $\frac{S''}{M''} = 0{\cdot}2774$

At Dundee, Mr. Mackie (*British Association, 7th Report*) has found by 7 months' observations from times . . $\frac{S''}{M''} = 0{\cdot}3420$.

In the *Philosophical Transactions*, 1836, page 305, Mr. Whewell has insisted on the difference of the extreme values of the semimenstrual inequalities $\left(\text{and the consequent difference of deduced values of } \frac{S''}{M''}\right)$ at different places, as ascertained by three weeks' observations. We have not the smallest confidence in such a result, having in our own observations, for four days only, encountered a discordance of two hours between the times occupied by two successive tides.

The proportions deduced from different places do not agree.

(538.) Confining ourselves now to the values of $\frac{S''}{M''}$, deduced from the times only, which are incomparably more exact than those deduced from the heights (the Brest and Plymouth observations excepted), the following remarks suggest themselves. The two places (London and Liverpool), at which the greatest number of observations have been made, agree precisely in the value which they give for $\frac{S''}{M''}$. Yet it seems impossible to deny that at some places (we particularly cite Plymouth and Bristol) the value of $\frac{S''}{M''}$ deduced from the times is certainly greater by $\frac{1}{10}$th part, and that at other places (as Portsmouth and Dundee) it is less by nearly $\frac{1}{10}$th part. And these we consider to be real and certain differences in the comparative effects of the Sun and Moon in the seas near to those places. They cannot be explained by any difference in the speed of spring-tide-waves and neap-tide-waves, as in (463.), because, by the rules of (536.), the value of $\frac{S''}{M''}$ is obtained by comparing two times of tide when (the values of $m-s-\alpha$ being the same with opposite signs) the magnitude of the tide, which depends on $\cos 2.\overline{m-s-\alpha}$, was the same. Indeed we consider it perfectly certain that the value of $\frac{S''}{M''}$ deduced from the times is an accurate representation of the proportion of the magnitudes of the solar and lunar tide-waves which come to the port. And the question now is, whether such a difference for different ports, as we consider to be established, is consistent with our theory? We answer that it is, and that it may be ascribed to one or more of the following causes.

(α.) If tides were formed independently (or nearly so) in different channels of different depths, the proportion of the solar and lunar waves, which by (455.) contains the factor $\frac{n''^2 b^2 - gk}{n^2 b^2 - gk}$, would be different in the different channels. This can scarcely apply to the different ports of England, but it may well apply in comparing the tides of the Atlantic with those of the Pacific.

(β.) If tides are communicated by different channels to the same port, the proportion of the solar and lunar waves, (121.) and (312.), will depend on the length, &c., of those channels, and may be different at different places. This applies, probably, to every port in England.

(γ.) The harbour-tides are, without exception, tides which have acquired a greater magnitude than the ocean-tides, in consequence of the tide having passed over a sloping bottom. Now though we cannot give accurately the values of the expressions used in (246.) and (247.), still it is certain that they will depend on n and m as well as on the depth and slope, and, therefore, that the solar and lunar tides will be altered in different degrees.

(539.) The difference in the values of $\frac{S''}{M''}$, therefore, however difficult to be explained from the actual circumstances of each port, presents no difficulty in the general theory. One point, however, we must specially remark. Our explanations of the difference depend entirely on the difference of the periodic times of the forces, and, therefore, the consideration introduced by Laplace (481.) for the varying alteration of the effect of *each* body as connected with its varying velocity in right ascension, applies to all of them. This consideration is embodied in our formulæ of (448.). And if the observations applying to this were properly treated, in a manner equivalent to that of Laplace, (481.), and if the observations were sufficiently numerous and good, we ought to obtain the same value of the Moon's mass from every port. Unfortunately, the philosophers who have reduced the English observations, do not appear to have been aware of the principle on which the true value of the mass may (theoretically, at least,) be deduced from $\frac{S''}{M''}$; Mr. Whewell has even expressly said (*Phil. Trans.*, 1838, page 245): "We see, therefore, how different the mass of the Moon would be found to be by calculations from the tide-observations of different places." This would be true for an equilibrium-theory; but, as that contemptible theory is entirely inapplicable, except for some forms which require such extensive changes that they are now useless, it is scarcely worth while to refer to it. For a wave-theory it is not correct. We shall have occasion to revert to this subject.

(540.) Now, considering the values of $\frac{S'''}{M'''}$ deduced from the vertical range of tide, we find that there are but three accurate determinations (those from Brest, Plymouth, and Bristol), to which that of Dundee may be added as somewhat inferior. They agree in giving a smaller value at each place than that given by the times. We cannot explain this, but we assert distinctly that there is nothing in it contradictory to theory in its present state. We believe it to depend upon circumstances purely local, upon the depth and breadth of the channels through which the tide passes, and the like. For here, unlike the case of (538.), the determination depends *entirely* upon the difference of spring tides and neap tides. The most singular circumstance is, that, apparently at London and Liverpool, and certainly at Plymouth (Whewell, *Phil. Trans.*, 1839, page 151, &c.), the semimenstrual inequality is greater for low water than for high water. That is, upon increasing the general magnitude of the sea-wave, it produces a greater effect on shore-low-water than on shore-high-water. From these observed facts, as well as from those of (513.), &c., we are induced to fix upon the subject partially discussed in the third subsection of Section IV., as more strongly deserving attention at the present time than any other point in the Theory of Tides.

(541.) 2nd. On the value of 2α. This is determined from the times by taking that value of $2.\overline{m-s}$ which is found from observation to give to θ at high water its mean value. For, if we take pairs of equal values of $\overline{m-s}-\alpha$ with opposite signs, we obtain pairs of equal values of $2\theta-2\lambda$ with opposite signs: the mean of all is $2\theta-2\lambda=0$, which corresponds to $2.\overline{m-s}-2\alpha=0$ or gives $2\alpha=$ the corresponding value of $2.\overline{m-s}$. We may here observe that the quantity λ, which is the value of θ corresponding to $2.\overline{m-s}-2\alpha=0$, or which is the mean value of θ, is that upon which Mr. Whewell has with great propriety fixed as the characteristic of the time of high water at any place. He has sometimes called it "the mean lunitidal interval," (or the mean hour-angle of the moon at high water,) or sometimes "the corrected establishment," for a reason to which we shall advert shortly.

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The value of 2α is determined from the heights by taking that value of $2.\overline{m-s}$ which gives to the height its greatest value. For, the expression for the height is evidently greatest when $2.\overline{m-s}-2\alpha=0$.

Since $m-s$ is the angle in right ascension by which the Moon has separated from the Sun, and since the mean separation in a solar day is 49 minutes nearly, the number of days after syzygy corresponding to the separation $\overline{m-s}$ (supposed to be expressed in minutes of time) is $\frac{m-s}{49}$ nearly, or $m-s=$ number of days × 49. Therefore α, if expressed in minutes of time $=49$ × number of days after syzygy, or α, if expressed in degrees, $=12°\,12'$ × number of days after syzygy, at which the lunitidal interval $=$ mean lunitidal interval, or at which the highest tide occurs. In the same manner, $\alpha=49^m$, or $12°\,12'$ × number of days after quadrature at which the lunitidal interval has its mean value, or at which the lowest tide occurs. At solstices (separately considered) these numbers are to be increased $\frac{1}{11}$th, and at equinoxes to be diminished $\frac{1}{12}$th.

Determinations from different places.

(542.) Thus the following determinations have been obtained:—

At Brest (*Méc. Cél.*, vol. v., pages 187 to 200), from observations of heights at equinoxial syzygies, the highest tide follows syzygy by $1^d\cdot480$, or . $\alpha=16°\ 36'$

At solstitial syzygies by $1^d\cdot547$, or . $\alpha=20°\ 29'$

From observations of heights at equinoxial quadratures, the lowest tide follows quadrature by $1\cdot5097$, or . $\alpha=19°\ 56'$

At solstitial quadratures by $1\cdot5127$, or $\alpha=16°\ 25'$

Laplace has not given the details of computation applying to the times, but he remarks that the hour of low water (expressed in fractions of a day) corresponding to the greatest tide, supposed to occur at $1^d\cdot5$ after syzygy, is $0\cdot441170$, and the hour of high water corresponding to the least tide, supposed to occur at $1^d\cdot5$ after quadrature, is $0\cdot431600$. If a later epoch were used, the first of these numbers would be increased by a less quantity than the Moon's daily motion ($\theta-\lambda$ being then negative, and increasing in its negative value), and the second would be increased by a greater quantity than the Moon's daily motion: and thus they might be made exactly equal. The value of $\overline{m-s}$ at this time would determine α. Thus it appears that α, as found from the times, is greater than as found from the heights. Mr. Lubbock, from one year's observations of times (*Phil. Trans.*, 1832), found . $\alpha=22°\ 0'$

At London, from times (Lubbock, *Phil. Trans.*, 1831, page 400) . . . . $\alpha=32°$
From heights (page 403) . . . $\alpha=26°$
At Liverpool, from times (Lubbock, *Phil. Trans.*, 1835, page 283; and Whewell, 1836, page 8, observing that the tide occurs 11 hours after the moon's transit) . . . . . . $\alpha=24° 15'$
From heights . . . . $\alpha=20° 30'$
At Bristol, from times (Whewell, *Phil. Trans.*, 1838, page 237), the value of α is the Moon's motion during 56 hours, or . . . . $\alpha=28° 30'$
From heights, the value of α is the Moon's motion during 40 hours, or . . . . $\alpha=20° 20'$
At Dundee, from times (Whewell, *Phil. Trans.*, 1839, page 157) . . . . $\alpha=23°$
From heights . . . . . . $\alpha=20°$
At Portsmouth, from times (Lubbock, *Phil. Trans.*, 1833, page 21) . . $\alpha=26° 30'$
At Plymouth, from times (same reference) . . . . $\alpha=28° 45'$
At Sheerness, from times (same reference) . . . . $\alpha=30°$

(543.) We have now to consider how the existence and variety of magnitude of this quantity α can be explained. And first we must remark that a part of it depends on the circumstance that we have not observed the tides in the ocean in which they are actually formed by the Sun and Moon, but on rivers and narrow seas up which they have been propagated as waves without external forces. Now the tide at London (the mean effect of two waves at 12 hours' interval, as we shall hereafter explain) has travelled from Brest in 16 solar hours nearly, and, therefore, to refer the London tide to its origin in that part of the Atlantic Ocean we must subtract from α the Moon's motion in 16 solar hours, or 8° 15′. In this manner we find the following table of values* of α referred to that part of the Atlantic ocean which is near Brest:—

Reduction of all the values of retard to one locality.

Place.	Number of hours occupied by passage of tide from Brest.	Corresponding correction to α.	Corrected value of α from times.	Corrected value of α from heights.
Brest . . .	0h. 0m.	0° 0′	22° 0′	18° 20′
London . . .	16 10	−8 15	23 45	17 45
Liverpool . .	7 40	−4 0	20 15	16 30
Bristol . . .	3 30	−1 50	26 40	18 30
Dundee . . .	10 50	−5 30	17 10	14 30
Portsmouth. .	7 52	−4 0	22 30	
Plymouth . .	1 45	−1 0	24 45	
Sheerness . .	14 51	−7 30	26 0	

The values of α from the heights agree as well as we can expect. The only sensible discordance is that of Dundee, where the result is deduced from the observations of a single year. The values of α deduced from the times cannot be made to agree.

(544.) Now a little consideration will show that the amount of α cannot possibly be explained by delay in the transmission of the tide. The smallest value of α implies a delay of 29 hours; while it will appear that the tide at the Cape of Good Hope is earlier by only 15 hours, and that at Cape Horn by a still smaller quantity, than that at Brest; and thus it would seem that, even in the southern sea, where no reason for delay of tide can be imagined, it has already been delayed at least 14 hours. Putting this aside, we shall at once state our conviction that the apparent delay arises entirely from friction, as explained from theory in (459.). We may remark that the expression there found has the same sign whether the depth of the sea be greater or less than 14 miles. We do not deny that it is possible to explain the same thing by the interference of two tides with nearly opposite phases, of which one has suffered no retardation, and the other a small retardation; and that, in the instance of Brest, two such mingling tides may be produced, one from S. to N., and the other from E. to W. But the other explanation is so much more natural that we shall adhere to it.

(545.) But, as we have one system of values of α given by the heights of tide, and another given by the times, it may be asked which is the true one? We answer, without doubt, that given by the heights. We have shown in (462.) that local circumstances do not alter, except by a constant quantity, the times of high water for a given range of tide, and therefore do not alter the day of highest tide (upon which α, as deduced from the heights, depends); but in (463.) it appears that local circumstances do alter the day when the tide occurs at mean lunitidal interval, or do alter the time for which the relative positions of the sun and moon are to be used in computation of the time of tide. They may be expected, therefore, to alter it differently in different ports, and thus the discordance of values of α in the first column is explained. It is remarkable that the difference between the time-values and the height-values of α is less at the two most open ports (Dundee and Brest) than at any of the others, as might have been expected.

(546.) It is, however, worthy of remark, that all the time-values of α are greater than the height-values. This implies that the effect of the local circumstances is opposite to that assumed in (463.), and therefore that the great tides travel more slowly from the sea than the small tides. We cannot venture positively to explain this, but we may suggest the following consideration for the reader's judgment. Before the old London Bridge was removed, the higher passage of small tides was materially obstructed by the sterlings of the bridge; that of great tides much less. The small tides were therefore nearly similar to tides in an interrupted canal, in which the time of high water is the same as that at the sea (307.); while the large tides partook of the nature of tides in an uninterrupted canal, and the time of high water up the river was progressive. Similar considerations may apply to the other ports. The quantity α is sometimes called the *retard*, and the time in which the Moon moves through that angle from the Sun is called the *age of the tide*.

(547.) 3rd. On the agreement of the laws of the observed semimenstrual irregularities with those given by the for-

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* We have been anxious to combine with these the value of α, deduced from the observations of height at Leith, which are tabulated in the Report of the 11th meeting of the British Association, page 36. But in the want of explanation of the table, and the apparent inference from it as it stands, that the highest tide *precedes* syzygy (contrary to universal experience), we have not ventured to use it.

mulæ. With regard to the times we may state, that for those places for which the comparison has been made with the values of $\frac{S''}{M''}$ and α peculiar to those places, the agreement is perfect. We subjoin a Table similar to Mr. Lubbock's, of observed and computed intervals between the Moon's transit over the meridian at London and the time of high water (altered only so as to adapt it to the value of $\alpha = 32°$ as above, instead of 30° which Mr. Lubbock has used,) and we copy from the *Philosophical Transactions*, 1836, Mr. Whewell's table of the observed and computed intervals for Liverpool.

Observed and computed values of θ for London; the computed values being found by the second formula of (535.), supposing $\frac{S''}{M''} = 0{\cdot}37887$, $\alpha = 32°$, λ (in time)$= 1^h.25^m.35^s$.

Comparison of theoretical law and observed law of semi-menstrual inequalities of time.

Solar Time of Moon's Transit.		$m-s$ at Moon's Transit.		$m-s$ at High Water.		$m-s-\alpha$.		Computed Value of $\theta-\lambda$ in Time.		Computed Value of θ in Time.			Observed Value of θ in Time.	
h	m	°	′	°	′	°	′	m	s	h	m	s	h	m
0	0	0	0	1	0	329	0	+31	42	1	57	17	1	57
0	30	7	30	8	30	336	30	+24	50	1	50	25	1	50
1	0	15	0	16	0	344	0	+17	16	1	42	51	1	42
1	30	22	30	23	20	351	20	+ 9	20	1	34	55	1	35
2	0	30	0	30	50	358	50	+ 1	18	1	26	53	1	26
2	30	37	30	38	20	6	20	− 6	59	1	18	36	1	18
3	0	45	0	45	40	13	40	−14	50	1	10	45	1	11
3	30	52	30	53	10	21	10	−22	32	1	3	3	1	3
4	0	60	0	60	30	28	30	−29	30	0	56	5	0	56
4	30	67	30	68	0	36	0	−35	44	0	49	51	0	51
5	0	75	0	75	30	43	30	−40	42	0	44	53	0	45
5	30	82	30	83	0	51	0	−43	50	0	41	45	0	43
6	0	90	0	90	30	58	30	−44	18	0	41	17	0	42
6	30	97	30	98	0	66	0	−41	18	0	44	17	0	44
7	0	105	0	105	30	73	30	−33	38	0	51	57	0	52
7	30	112	30	113	10	81	10	−20	20	1	5	15	1	5
8	0	120	0	120	50	88	50	− 2	50	1	22	45	1	23
8	30	127	30	128	20	96	20	+15	7	1	40	42	1	39
9	0	135	0	136	0	104	0	+29	54	1	55	29	1	56
9	30	142	30	143	30	111	30	+39	18	2	4	53	2	5
10	0	150	0	151	0	119	0	+43	46	2	9	21	2	10
10	30	157	30	158	30	126	30	+44	20	2	9	55	2	10
11	0	165	0	166	0	134	0	+42	0	2	7	85	2	8
11	30	172	30	173	30	141	30	+37	34	2	3	9	2	3

Observed and computed values of $\theta-\lambda$ for Liverpool, supposing $\frac{S''}{M''} = 0{\cdot}37866$, and $\alpha = 24°.15'$ nearly. (*Note.*—Our α is not the same quantity as Mr. Whewell's α, *Philosophical Transactions*, 1836, page 8. Mr. Whewell uses α as the correction to the Moon's distance from the Sun at the time of transit preceding the tide; ours is the correction to the Moon's distance from the Sun at the time of high water.) λ for Liverpool is $11^h\ 6^m$.

Solar Time of Moon's Transit.		Computed Value of $\theta-\lambda$.		Observed Value of $\theta-\lambda$.		Solar Time of Moon's Transit.		Computed Value of $\theta-\lambda$.		Observed Value of $\theta-\lambda$.	
h	m	m	s	m	s	h	m	m	s	m	s
0	30	+12	16	+12	12	6	30	−25	8	−25	0
1	30	− 4	7	− 4	36	7	30	+ 9	2	+ 9	6
2	30	−20	6	−20	0	8	30	+36	28	+36	36
3	30	−34	0	−33	54	9	30	+44	20	+45	36
4	30	−43	6	−42	48	10	30	+39	40	+39	48
5	30	−42	40	−43	12	11	30	+27	36	+26	6

It would scarcely be possible to obtain closer agreement. In figure 61 we have represented the values of $\theta-\lambda$ for London by the ordinates of a curve, the abscissa representing the solar time of the Moon's transit. The dark line is the curve representing the values of $\theta-\lambda$ computed from theory, and the dotted line is that representing the observed values. The same form precisely is given by the observations at other places; we leave to the reader the task of laying down that for Liverpool, and we refer him to the *Philosophical Transactions*, 1833, page 19, for the curves of six different places.

Tides and Waves.

Difference between Vulgar Establishment and Corrected Establishment.

(548.) We may now point out the difference between the vulgar *Establishment* of which we have spoken in (2.) and (497.), and Mr. Whewell's *Corrected Establishment.* At London, for instance, the vulgar Establishment, taken from the table above, would be $1^h\ 57^m$. But the mean interval between the Moon's transit and the time of high water is $1^h\ 25^m\ 35^s$; and this is the *Corrected Establishment*, differing 31^m from the other. It is better for adoption as a mathematical element, because it expresses a simple quantity (namely, the delay of high water after the Moon's transit, supposing no Sun to exist); and it is better for practical use, because it differs less, upon the whole, from the real interval on any day, than the vulgar Establishment does. Thus at London, if we roughly computed the time of high water with the interval $1^h\ 57^m$ from Moon's transit, we might sometimes be $1^h\ 15^m$ in error; if we used $1^h\ 26^m$, we should never be more than 44^m in error.

Comparison of theoretical and observed law of semimenstrual inequalities of heights.

(549.) With regard to the heights, it is possible to use such constants in the second formula of (535.) as will give a very close approximation to the observed heights. Thus, for the representation of the heights of high water at Liverpool, Mr. Whewell has used the values $M'=6\cdot872$ feet, $S'=2\cdot74$ feet, $\alpha=15°$ (applicable to the Moon's distance from the Sun at the preceding transit), and has subtracted from the result of the computation, the constant 7·19 (the mean of all the computed numbers). This he compares with the difference between each of the heights, and the mean of all the heights, as measured from a certain fixed point. The result is as follows:—

Solar Time of Moon's Transit.		Difference of computed height from mean.	Difference of observed height from mean.
h	m	Feet.	Feet.
0	30	+2·35	+2·35
1	30	+2·35	+2·39
2	30	+1·83	+1·88
3	30	+0·84	+0·90
4	30	−0·48	−0·38
5	30	−1·89	−1·76
6	30	−2·90	−2·91
7	30	−2·90	−2·94
8	30	−1·89	−1·85
9	30	−0·48	−0·38
10	30	+0·84	+1·04
11	30	+1·83	+1·81

The agreement is good, but it has been obtained only by taking for M″ a quantity which shall make a good agreement, and not by taking it from the range of the tide. To make an equally good agreement for the heights in the London tides (*Phil. Trans.*, 1831, page 390), it is necessary to use a value of M″ much smaller than that used by Mr. Lubbock, so that the value of $\frac{S''}{M''}$ is unreasonably large. But, for the reasons mentioned in (540.), we do not think this important. In figure 62 we give the curve representing the semimenstrual inequality of height for London; the abscissa is the Moon's solar time of transit, and the ordinate is the height of high water above a fixed point.

(550.) We now come to the corrections in these semimenstrual formulæ depending on the varying declinations and varying distances of the Moon and Sun. And first, the correction for the Moon's declination. The term which the equilibrium-theory gives for correction of time, (54.) and (56.), is

$$-\frac{360^m}{\pi}.\frac{M_{\Delta}S_{\Delta}.\sin 2.\overline{m-s}}{(M_{\Delta}+S_{\Delta}.\cos 2.\overline{m-s})^2\cos^2\Delta}(\sin^2\mu-\sin^2\Delta)$$

and that for correction of height, (53.) and (56.),

$$-3.\frac{M_{\Delta}^2+M_{\Delta}S_{\Delta}.\cos 2.\overline{m-s}}{\surd\{M_{\Delta}^2+2.M_{\Delta}S_{\Delta}.\cos 2.\overline{m-s}+S_{\Delta}^2\}\cos^2\Delta}(\sin^2\mu-\sin^2\Delta)$$

where the whole height is represented by $3\surd\{M_{\Delta}^2+2M_{\Delta}S_{\Delta}.\cos 2.\overline{m-s}+S_{\Delta}^2\}$. Here μ is the Moon's declination, and μ and $\overline{m-s}$ are to be taken for the time of the tide. The theory of waves, (448.), (449.), and (452.), makes several important modifications in this expression. First μ and $\overline{m-s}$ are to be taken for a time anterior by a *constant* quantity $\rho_{\prime}$ (452.) and (459.), (not by a quantity which makes α constant). This quantity $\rho_{\prime}$ for Brest is about 36 hours, for London 52 hours, for Liverpool 44 hours, and for Bristol 40 hours. Secondly, in computing the retardation or its tangent, or $\theta-\lambda$ (the expression which in (535.) we have found it necessary to use) from the formula

Formulæ for lunar declination corrections of times.

$$-\frac{360^m}{\pi}\times\frac{(S_{\Delta}+T).\sin 2.\overline{m-s}}{M_{\Delta}+N+(S_{\Delta}+T)\cos 2.\overline{m-s}}$$

and in computing the height from the formula

$$\surd\{M_{\Delta}^2+2M_{\Delta}S_{\Delta}.\cos 2.\overline{m-s}+S_{\Delta}^2+(2M_{\Delta}+2S_{\Delta}.\cos 2.\overline{m-s})N+(2S_{\Delta}+2M_{\Delta}.\cos 2.\overline{m-s})T\},$$

we must increase $2m$ further by $\frac{n'b^2l}{n'^2b^2-gk}\omega^2.\sin 2lt$ (ω=obliquity of Moon's orbit to equator, lt=Moon's longitude or right ascension); and for M+N, so far as depends on declination, we must put

$$M\left\{1-\frac{\omega^2}{2}+\left(\frac{1}{2}-\frac{n'b^2l}{n'^2b^2-gk}\right)\omega^2\cos 2lt\right\}.$$

The mean of all the values of this expression is $M.\cos^2\Delta$, or $M_\Delta = M\left(1-\frac{\omega^2}{2}\right)$, and this expression is therefore

$$M_\Delta\left\{1+\frac{1}{\cos^2\Delta}\left(\frac{1}{2}-\frac{n'b^2l}{n'^2b-gk}\right).\left(\omega^2-\omega^2.\overline{1-\cos 2lt}\right)\right\}$$

$$=M_\Delta\left\{1+\frac{1}{\cos^2\Delta}\left(1-\frac{2n'b^2l}{n'^2b^2-gk}\right)\left(\frac{\omega^2}{2}-\omega^2.\sin^2lt\right)\right\}$$

$$=M_\Delta\left\{1-\left(1-\frac{2n'b^2l}{n'^2b^2-gk}\right).\frac{\sin^2\mu-\sin^2\Delta}{\cos^2\Delta}\right\}.$$

$$\text{Therefore } N=-M_\Delta\left(1-\frac{2n'b^2l}{n'^2b^2-gk}\right)\frac{\sin^2\mu-\sin^2\Delta}{\cos^2\Delta}.$$

Also, putting $2m'$ for $\frac{n'b^2l}{n'^2b^2-gk}\,\omega^2.\sin 2lt$, $\sin 2.\overline{m-s}$ is to be changed to $\sin\overline{2m-2s+2m'}=\sin 2.\overline{m-s}+2m'.\cos 2.\overline{m-s}$, and $\cos 2.\overline{m-s}$ is to be changed to $\cos\overline{2m-2s+2m'}=\cos 2.\overline{m-s}-2m'.\sin\overline{2m-s}$. Omitting therefore all variations depending on the varying distance and declination of the sun, and all except those of declination of the moon, we have to compute the time of tide after transit, or $\theta-\lambda$, by the formula

$$-\frac{360^m}{\pi}\times\frac{S_\Delta\{\sin 2.\overline{m-s}+2m'.\cos 2.\overline{m-s}\}}{M_\Delta+N+S_\Delta\{\cos 2.\overline{m-s}-2m'.\sin 2.\overline{m-s}\}}$$

or (expanding to the first power of N and $2m'$), by the formula

$$-\frac{360^m}{\pi}.\frac{S_\Delta.\sin 2.\overline{m-s}}{M_\Delta+S_\Delta.\cos 2.\overline{m-s}}-\frac{360^m}{\pi}.2m'\frac{M_\Delta S_\Delta.\cos 2.\overline{m-s}+S_\Delta^2}{(M_\Delta+S_\Delta.\cos 2.\overline{m-s})^2}+\frac{360^m}{\pi}N.\frac{S_\Delta.\sin 2.\overline{m-s}}{(M_\Delta+S_\Delta.\cos 2.\overline{m-s})^2};$$

and putting for N and m' their values, we have for the second and third term, which constitute the declination-correction of time of high water,

$$-\frac{360^m}{\pi}\left\{\frac{n'b^2l}{n'^2b^2-gk}\,\omega^2.\sin 2lt.\frac{M_\Delta S_\Delta.\cos 2.\overline{m-s}+S_\Delta^2}{(M_\Delta+S_\Delta.\cos 2.\overline{m-s})^2}\right.$$
$$\left.+\left(1-\frac{2n'b^2l}{n'^2b^2-gk}\right)\frac{\sin^2\mu-\sin^2\Delta}{\cos^2\Delta}.\frac{M_\Delta S_\Delta.\sin 2.\overline{m-s}}{(M_\Delta+S_\Delta.\cos 2.\overline{m-s})^2}\right\}.$$

We proceed now to advert to the bearing of observations, as far as they have yet been discussed, upon these terms.

One term has been omitted in comparisons with observations.

(551.) The first term, depending upon $\omega^2\sin 2lt$, has not been elicited from observations at all, for very good reasons. The square of the sine of declination is $\omega^2\sin^2lt$, and therefore $\omega^2\sin 2lt$ is proportional to the increase of the square of the sine of declination. Now Laplace gave very little attention to the times of tides; and moreover, in the discussion of solstitial and equinoxial observations, he confined himself to the times bordering very closely on solstices and equinoxes, on both sides of them (480.), &c., and therefore the increase of the square of declination could not appear. Mr. Lubbock and Mr. Whewell, though they have used observations made with all values of declination, have unfortunately (from inattention to this theory) classified the tides, as regards declination, only by the amount of declination, grouping together the observations at which the declination was increasing and those at which it was diminishing: in the mean of these, therefore, the term depending on the increase or decrease of declination has been entirely lost. We regret this much, because that term would be of singular use in giving the value of the important constant $\frac{n'^2b^2l}{n'^2b^2-gk}$; of which we shall shortly speak further.

(552.) For the second term, the observations were arranged with reference to the declination, (though somewhat complicated at first by the introduction of the calendar month,) and they are therefore so far in a fit state to compare with theory. It must be remarked that m, s, and μ, are to be taken for the moon's place at a period anterior by that constant which we have called the *age of the tide* or $\rho_{\prime}$; and therefore that the interval of the time of tide from the moon's transit, or $\theta-\lambda$, ought not to be reckoned from the last transit of the moon, but from that transit of the moon over some meridian at which it occurred at the time $\rho_{\prime}$ nearly before the tide. Mr. Whewell, in discussing the intervals of tides from the nearest transit of the moon at London and Liverpool, (*Phil. Trans.* 1834 and 1836,) found, besides terms multiplying $\sin 2.\overline{m-s}$, terms of the form $132^m(\sin^2\Delta-\sin^2\mu)$ for London, and $84^m.(\sin^2\Delta-\sin^2\mu)$ for Liverpool. These terms, not at first understood, are a singular proof of the theory as regards the necessity of referring the interval to a transit earlier by the age of the tide. For the moon's velocity in right ascension $=$ vel. in long. $\times\frac{\cos\text{ obliquity}}{\cos^2\text{ declination}}=$ vel. in long. $\times\frac{\cos^2\Delta}{\cos^2\mu}=$ vel. in long. $\times(1-\sin^2\Delta+\sin^2\mu)$, therefore, supposing the theory correct, the moon's right ascension or time of transit would be increased, from the true anterior epoch to the transit near to the time of tide, by vel. in long. × age of tide $\times(1-\sin^2\Delta+\sin^2\mu)$ or by $\alpha\times(1-\sin^2\Delta+\sin^2\mu)$; of which the part that depends on declination is $\alpha\times(\sin^2\mu-\sin^2\Delta)$; and therefore the interval from that transit to the tide would be increased by $\alpha(\sin^2\Delta-\sin^2\mu)$; which, with the values above for α, gives for London $128^m(\sin^2\Delta-\sin^2\mu)$, and for Liverpool about $80^m(\sin^2\Delta-\sin^2\mu)$, (referring the end of α, in Mr. Whewell's manner, to the place of the moon at the transit preceding the tide;) the agreement of which with the quantity deduced from observation is very close.

Explanation of a difficulty produced by using a wrong place of the moon.

Difficulty of comparing theory with existing results of observation.

(553.) The general comparison, however, of the results for declination-correction of times deduced by Mr. Whewell (*Philosophical Transactions*, 1834, 1836, 1838) with the term given by theory, is almost impracticable. Where the tide ought to be compared with a transit of the moon earlier by two days, it is evidently unsafe to attempt to use results deduced from comparison with a transit on the same day, especially for an element which changes so rapidly as declination, and more particularly as one term whose influence would probably then be sensible is entirely neglected. This consideration excludes all but the investigation in the *Philosophical Transactions*, 1838. In that paper Mr. Whewell has gone through the labour of reducing two years' observations at Bristol by reference to three different transits of the moon, (a process which, with proper management, would give the results depending on the change of the moon's declination and change of the moon's elliptic inequality, which we are seeking;) and he finds that the same transit (B), to which it is necessary to refer for semi-menstrual inequality of height, will give a declination-correction agreeing *generally* with theory. But how nearly this agreement holds is not explained. Our theoretical term is

$$-\frac{360^{m}}{\pi}\left(1-\frac{2n'b^2l}{n'^2b^2-gk}\right)\frac{\sin^2\mu-\sin^2\Delta}{\cos^2\Delta}\cdot\frac{M_{\Delta}S_{\Delta}.\sin.2.\overline{m-s}}{(M_{\Delta}+S_{\Delta}.\cos 2.\overline{m-s})^2};$$

Mr. Whewell's has the form + a factor × $s\,(2\phi-12^h)$, s being a periodical function which is positive when its argument is less than 12^h and negative when its argument is between 12^h and 24^h, and has for maximum and minimum values +1 and −1, these values occurring, the first before 6^h in the argument, and the second after 18^h. (This appears clearly, from the instance p. 239, to be the nature of the curve.) Now this law agrees well with that of the theory. The factor is $+6^m$ for declination 24° and -7^m for declination 7°; or the difference for decl. 24° and decl. 7° is 13^m. But if from the theoretical term we compute, with $\frac{S_{\Delta}}{M_{\Delta}}=0{\cdot}394$, as found from the times at Bristol (537.), the maximum value of that term (occurring when $2.\overline{m-s}=129°$), we find the difference of its values for declination 7° and 24° to be $10^m{\cdot}1\times\left(1-\frac{2n'b^2l}{n'^2b^2-gk}\right)$. Are we to make this equal to 13^m, and to infer from it that gk is greater than n'^2b^2, or that (444.) the depth of the sea is greater than 14 miles? We think not. Calculations on the equilibrium-theory, assuming the received mass of the moon (33.) and (35.), give for the proportion of the moon's effect to the sun's effect 0·596 : 0·271, or 1 : 0·45 nearly; and the only way in which we can explain the raising of that ratio to the proportion 1 : 0·394 is by supposing n'^2b^2-gk to be positive. (455.) A contradiction of the same kind will be found if we use any other supposition, as Laplace's: but will the reduced observations justify us in drawing any theoretical deduction? We scarcely think that they will. Independently of the general omission of steps of the reduction, we may remark that, as appears from Mr. Whewell's description of the mode of reducing, (extracted in 494.) the means of corrections were supposed to apply to the means of declinations, instead of to the means of the squares of declinations. This error cannot fail to injure the whole deduction.

Formulæ for lunar declination-correction of heights.

(554.) The declination-correction for heights will be thus found. In the expression

$$\sqrt{\{M_{\Delta}^2+2M_{\Delta}S_{\Delta}.\cos 2.\overline{m-s}+S_{\Delta}^2+(2M_{\Delta}+2S_{\Delta}.\cos 2.\overline{m-s})N\}},$$

(53.), (56.), and (535.), omitting T, we are to put $\cos 2.\overline{m-s}-2m'.\sin 2.\overline{m-s}$ for $\cos 2.\overline{m-s}$; and then to expand to the first power of m' and N. This gives for the small terms

$$-2m'\frac{M_{\Delta}S_{\Delta}.\sin 2.\overline{m-s}}{\sqrt{\{M_{\Delta}^2+2M_{\Delta}S_{\Delta}.\cos 2.\overline{m-s}+S_{\Delta}^2\}}}+N\frac{M_{\Delta}+S_{\Delta}.\cos 2.\overline{m-s}}{\sqrt{\{M_{\Delta}^2+2M_{\Delta}S_{\Delta}.\cos 2.\overline{m-s}+S_{\Delta}^2\}}};$$

or, restoring for m' and N their values, the small terms are

$$-\frac{n'b^2l}{n'^2b^2-gk}\omega^2\sin 2ll.\frac{M_{\Delta}S_{\Delta}.\sin 2.\overline{m-s}}{\sqrt{\{M_{\Delta}^2+2M_{\Delta}S_{\Delta}.\cos 2.\overline{m-s}+S_{\Delta}^2\}}}$$

$$-\frac{M_{\Delta}^2+M_{\Delta}S_{\Delta}.\cos 2.\overline{m-s}}{\sqrt{\{M_{\Delta}^2+2M_{\Delta}S_{\Delta}.\cos 2.\overline{m-s}+S_{\Delta}^2\}}}\left(1-\frac{2n'b^2l}{n'^2b^2-gk}\right).\frac{\sin^2\mu-\sin^2\Delta}{\cos^2\Delta}.$$

Now the first of these terms has been neglected, for the same reasons which we have assigned in (551.). The treatment of the second term by English mathematicians has been unsatisfactory, in the same manner as that for the declination-correction of times. Moreover, as the whole range has not been observed, except at Plymouth, it can generally lead to no result as to the value of $1-\frac{2n'b^2l}{n'^2b^2-gk}$; and at Plymouth the two phases (high and low water) appear to depend upon such different laws that we cannot use the variations for high water only in conjunction with the whole range.

Laplace's deduction of the mass of the moon from de-

(555.) Laplace's deductions for the whole ranges of tide at Brest are so important that we must devote a few words to them. The proportion of the small term above to the whole mean range is

$$\frac{M_{\Delta}^2+2M_{\Delta}S_{\Delta}.\cos 2.\overline{m-s}}{M_{\Delta}^2+2M_{\Delta}S_{\Delta}.\cos 2.\overline{m-s}+S^2}\left(1-\frac{2n'b^2l}{n'^2b^2-gk}\right).\frac{\sin^2\mu-\sin^2\Delta}{\cos^2\Delta}.$$

clination-corrections.

Now Laplace had found $\frac{S_\vartriangle}{M_\vartriangle}$, as we have explained (536.); and using this value with the values of $\overline{m-s}$ and μ in the observations which he discussed, and comparing the difference of the observed ranges when $\mu=0$ and $\mu=23°$, and the ratio of that difference to the whole range, with the formula, he obtained a value for $1-\frac{2n'b^2l}{n'^2b^2-gk}$, and therefore for $\frac{n'b^2l}{n'^2b^2-gk}$, or for $\frac{l}{n'}\cdot\frac{\frac{n'^2b}{g}}{\frac{n'^2b}{g}-\frac{k}{b}}$. It is evident that $\frac{n'}{l}$ = number of lunar days in moon's sidereal period; that $\frac{n'^2b}{g}=\frac{n'^2}{n^2}\cdot\frac{n^2b}{g}=\left(\frac{\text{solar day}}{\text{lunar day}}\right)^2$ × the proportion of centrifugal force at the equator to gravity; and that $\frac{k}{b}$ is a constant which in our theory represents the proportion of the depth of the sea to the earth's radius. Thus a constant in Laplace's theory, analogous to the depth of the sea in our theory, was found. Then using that constant in the fraction discussed in (455.), he finds that the proportion of the moon's effect to the sun's has been *increased*, in consequence of this value of the depth of the sea, in the ratio of 4 : 5. (In his first investigations he had found the ratio to be 10 : 11.) That is to say, $\frac{M_\vartriangle}{S_\vartriangle}$ or $\frac{M''}{S''}=\frac{5}{4}\cdot\frac{M'}{S'}$. Now $\frac{M''}{S''}$ is known from the semimenstrual inequality; therefore $\frac{M'}{S'}$ is known; and (43.)

$$\frac{M'}{S'}=\frac{M}{(\text{Moon's distance})^3}\cdot\frac{(\text{Sun's distance})^3}{S};$$

and the sun's and moon's distances and the sun's mass are known, therefore the moon's mass is known. Thus Laplace found for the moon's mass a value very nearly $=\frac{1}{75}$ of the earth's mass.

It is to be remarked that Laplace's expressions are more complicated because (as is evidently necessary for accuracy) he combines, with these considerations applying to the moon's declination, analogous considerations applying to the sun's declination. Moreover, Laplace does not ascribe the alteration of the proportion of effects to the depth of the sea, (his own theory not admitting of a solution so general as to exhibit that effect,) but to the assumed interference of waves coming by different channels. But the expressions introduced are exactly the same. We cannot sufficiently admire the union of sagacity and ingenuity in this process; the sagacity of perceiving that the effects would not be proportionate to the forces, but would also depend on the periodic times of the forces; and the ingenuity of inventing a conceived combination of circumstances which, mathematically speaking, would account for the difference of proportion and would afford means of calculating it, but which probably were not the grounds of his original conjecture, and which can scarcely be supported as applicable, locally, to Brest. We do not at all imagine that Laplace believed in his hypothesis of two canals.

(556.) We shall not delay long on the corrections for the moon's varying parallax. It will be sufficient to state here that, in conformity with (448.) and (452.), $2.\overline{m-s}$ ought to be increased by $\frac{3n'b^2h}{n'^2b^2-gk}e\sin ht$; and that instead of using $1+3e\cos ht$ as representing the factor for the effect of the moon depending on parallax, we ought to use $1+\left(3+\frac{4n'b^2h}{n'^2b^2-gk}\right)e\cos ht$. The former of these terms is lost in all the investigations, for the same reason as the analogous term in the declination-corrections. In a discussion of the Liverpool tide-observations, (*Philosophical Transactions*, 1836,) Mr. Whewell found that the correction of the time of high water for parallax implied that the coefficient $3e$, instead of being increased, was to be diminished. But we attach little importance to this, as in that discussion the tides were compared with the next preceding transit of the moon, and the parallaxes, &c., were taken for that transit, instead of taking one long before it. In the *Philosophical Transactions*, 1838, the Bristol observations were discussed in reference to several transits in order to ascertain which gave the most consistent results for parallax-correction. The result was that a transit later than that which represented best the semimenstrual inequality and the declination-correction was necessary for the parallax-correction. But this conclusion is by no means certain. It was founded upon the consideration that such a transit made it unnecessary to introduce any constant multiple of p', and therefore brought the observed inequality to a form approaching nearly to the term in (54.). But, on the other hand, an earlier epoch (the same which gave best results for semi-menstrual inequality of height and for declination-correction) exhibited more distinctly, in the magnitude of the coefficient of the variable term, the influence of the parallax-correction; and this alone is a strong proof that the earlier epoch was better. Moreover, the existence of a constant multiple may be accounted for by the supposition, that the larger tide corresponding to a larger parallax, travelling further up the small river above Bristol, does not make high water at Bristol so soon as a smaller tide which is almost stopped there. The law of the variable part of correction obtained by Mr. Whewell, as depending on the interval of the sun and moon, agreed pretty well with the theoretical law.

Difficulty of comparing them with existing results of observation.

(557.) In the same place, Mr. Whewell has stated the result of reducing the observed heights of the tides at Bristol. It appears that the same age of the tide which represents the other inequalities is proper for this. With respect to the agreement of the law of correction, as depending on the moon's distance from the sun, we can pronounce nothing precise. Mr. Whewell has however stated that this factor is, from observations, nearly constant; which agrees with theory; inasmuch as the theoretical term

$$\frac{M_{\triangle}+S_{\triangle}\cos 2.\overline{m-s}}{\sqrt{\{M_{\triangle}^2+2M_{\triangle}S_{\triangle}\cos 2.\overline{m-s}+S_{\triangle}^2\}}}$$

differs from 1 only by a quantity of the order of $\left(\frac{S_{\triangle}}{M_{\triangle}}\right)^2$, and not of the order of $\frac{S_{\triangle}}{M_{\triangle}}$, as Mr. Whewell has stated.

(558.) The effect of parallax on the height of the tides at Brest was discussed by Laplace in the following manner. From the discussion of the declination-observations, to which we have already alluded (555.), he took the value of the quantity $\frac{n'b^2l}{n'^2b^2-gk}$. He then substituted this, as a known quantity, in the expression $\left(3+\frac{4n'b^2l}{n'^2b^2-gk}\cdot\frac{h}{l}\right)e\cos ht$, and computed with it the ranges of tides for large parallaxes and small parallaxes, and took their differences. Thus he obtained as a computed number representing the theoretical sum of the differences for a certain number of observations, 51·52. The number actually deduced from the observations themselves was 47·27. Thus the observed difference was less than the theoretical difference. But this theoretical difference, it must be remarked, depends entirely on the circumstance that Laplace has chosen to use only the declinations for finding $\frac{n'b^2l}{n'^2b^2-gk}$; whereas, in our opinion, both declinations and parallaxes ought to have been used, and a value of that quantity ought to have been found from their combination.

Laplace's comparison of observed parallax-inequality with theoretical corrections.

Verification of the theoretical law depending on the magnitude of declination and parallax.

(559.) The theoretical law of the declination and parallax-corrections (that they depend on the square of the sine of declination and on the simple difference of the parallax from mean parallax) is fully proved by Mr. Whewell in the various discussions of the tides at London, Liverpool, and Bristol, to which we have so often referred. It may be interesting to the reader to remark that the whole difference in the height of high water at London, depending on declination, is about six or eight inches, and that depending on parallax is about one foot; and that at Liverpool the corresponding quantities are nearly two feet and three feet. At Bristol they are greater.

Observed inequalities depending on the sun's place.

(560.) The corrections depending on the sun's declination and parallax, being much smaller than those for the moon, (both because the absolute effect of the sun is less, and because the proportionate variations of its distance are less,) are not so easily extracted from observations. But in the *Philosophical Transactions*, 1836, pages 131 and 218, Mr. Whewell and Mr. Lubbock, taking the observations at Liverpool and London, and subtracting the effects due to semi-menstrual inequality and to corrections for the moon's declination and parallax, have obtained those which depend on the sun's place. The results appear to agree well with theory. Those at London are more completely worked out by Mr. Lubbock (the observations being referred to an earlier transit) in the *Philosophical Transactions*, 1837, p. 97, &c. In the *Ninth Report of the British Association*, p. 13, will be found some results as to solar corrections deduced by Mr. Bunt from the observations at Bristol.

(561.) The second line of (44.), which is considered at length in (46.), (47.), and (48.), contains the expression for the diurnal tide. The reader will readily understand that, upon applying to these terms the theory of (439.), modified by the theory of friction nearly as in (451.), results of the same kind but with different constants will be obtained; the relative effects of the sun and moon will be altered in a proportion different from that of the alteration in the semi-diurnal tide; the magnitude of the tide will be determined by the positions of the bodies at an epoch anterior by a different quantity; and the absolute time of diurnal high water on any day will bear no distinct relation to that of semi-diurnal high water. In fact, the diurnal tide is to be worked out with little reference to the semi-diurnal tide.

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(562.) In (63.) we have pointed out the way in which the diurnal tide shows itself most obviously, by making the two semidiurnal tides appear unequal. Many notices of this kind are to be found in early records (as *Philosophical Transactions*, 1668, Colepresse on the tides at Plymouth, and Sturmy on those at Bristol: 1684, Davenport on those at Tunkin: 1776, a remarkable instance of their effect on the coast of New Holland, described by Captain Cook, &c.) In the same manner, observing the times as well as the heights of tide, it has been extracted from later observations. Thus in the *Philosophical Transactions*, 1836, page 57, &c., Mr. Lubbock has found that at Liverpool, in the month of January, when the moon's transit occurs in the afternoon at any time before 8 hours 30 minutes P.M., or in the forenoon after 8 hours 30 minutes A.M., the high tide which precedes that transit is greater than the high tide which follows it by a quantity which varies in magnitude, but which when greatest is nearly a foot. But if the moon's transit occurs at the opposite time of the day, the high tide which precedes that transit is less than that which follows it. The same rule applies to February, if, instead of 8 hours 30 minutes, we take 7 hours 30 minutes; for March, we must take 6 hours 30 minutes; for April, 3 hours 20 minutes; for May, 0 hours; for June, 9 hours in the opposite part of the day; and so on. The maximum difference is greatest in January and July, and least in April and October. From this it is plain that a considerable part of the diurnal tide depends on the sun. In the middle of January the sun's right ascension is 19 hours 30 minutes nearly; therefore the moon's right ascension, when her transit occurs at 8 hours 30 minutes P.M., is 4 hours nearly, and the diurnal tide therefore does not vanish till several days (5 or 6) after the moon has crossed the equator. The same appears from the other months. There is no sensible diurnal inequality in times. Mr. Lubbock (*Philosophical Transactions*, 1837, page 101) considers that the Liverpool diurnal tide corresponds to the position of the moon 4 days before the tide.

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(563.) In the *Philosophical Transactions*, 1836, page 289, &c., in which Mr. Whewell has given the results of the simultaneous observations of tides made at his representation on a great extent of coasts of Europe and America, he has stated the relation of the diurnal inequality to the position of the moon. On the North American coast, it corresponds to the moon's place at the same time; on the coast of Spain, Portugal, the west of France, Cornwall, the west of Ireland, the north of England and Scotland, and the Cape of Good Hope, it corresponds to the moon's place 2 days earlier;

at Cowes, Portsmouth, &c., to the place 4 days earlier. These differences suggested the notion that the diurnal wave travelled at a different rate from the semidiurnal wave. To ascertain this, a very admirable investigation was given by Mr. Whewell in the *Philosophical Transactions*, 1837, page 227, &c. The height of low water as well as high water on every day for 19 days having been observed, the effect of diurnal inequality at high waters separately and at low waters separately was found by the use of curves, as is described in (494.). Thus the effect of diurnal tide was ascertained at four times in each diurnal tide; these being used as ordinates, the curve drawn through them represented the diurnal wave; and the time of its maximum was easily found and compared with the time of semidiurnal high water. Thus from Ferrol, by the west coast of Ireland and north coast of Scotland to Lincolnshire, it precedes one of the semidiurnal tides about $3\frac{1}{2}$ hours, (with some irregularities); so also from Ferrol to Havre; but at Bridport the two tides are together, and at Lulworth and Portsmouth the diurnal tide is 4 or 5 hours later, after which it is traced with difficulty. It is to be remarked that in this paper Mr. Whewell considers the position of the moon, on which the diurnal tide depends, to be 4 days earlier than the tide (instead of 2 days for many of the places, as stated before). This seems to reconcile the phænomena much better, though it shows the great uncertainty of the conclusions from observation.

(564.) In the same volume, page 75, &c., Mr. Whewell has treated the diurnal tide at Plymouth and Singapore, and finds that the Plymouth tide corresponds to a position of the moon 4 days earlier, and that at Singapore to a position $1\frac{1}{2}$ day earlier. He remarks, however, that the agreement is best in May, June, and July, and that there are discrepancies in March, April, and August. We imagine that this arises from the circumstance that Mr. Whewell has nowhere taken account of the sun's part of the diurnal tide; and if this is sensible, (and the Liverpool observations discussed by Mr. Lubbock seem to show that in January and June it is not much inferior to the moon's part,) Mr. Whewell's determination of the corresponding position of the moon is worth little. We consider this subject as still open to investigation.

(565.) That the tide should follow the sun's and moon's positions by four days is quite conceivable on the theory of canals. The investigation of (451.) and (452.), putting n for $2n$, applies to diurnal tide; and thus we find for the interval preceding the tide at which the moon's place is to be used,

$$\frac{f b^2 (n^2 b^2 + 4 g k)}{(n^2 b^2 - 4 g k)^2}.$$

Now this retard may be considerably greater than

$$\frac{f b^2 (4 n b^2 + 4 g k)}{(4 n^2 b^2 - 4 g k)^2}$$

if the value of k be much nearer to $\frac{n^2 b^2}{4 g}$

than to $\frac{n^2 b^2}{g}$;

that is, if the depth of the sea be much nearer to $8\frac{1}{2}$ miles than to 14 miles.

(566.) Laplace, in the fifth volume of the *Mécanique Céleste*, page 226, has determined the effect of diurnal tide at solstitial syzygies at Brest, to be about 7 inches at high water, (increasing one and diminishing another each by $3\frac{1}{2}$ inches,) and about 5 inches at low water. And he has found from this that the diurnal tide precedes one of the semidiurnal tides by 2 hours 17 minutes nearly, which, though not quite accordant with Mr. Whewell's determination, agrees perhaps as nearly as can be expected.

Cause of doubt in the results as to epoch of diurnal tide.

(567.) There is, however, one cause of doubt in these determinations, to which we must call the reader's attention. We have seen that, in examining the fluctuations of height of high water depending on semimenstrual fluctuations of force (537.), the effect is far less than seems properly to be expected from the cause, and in one instance at least it is smaller than at low water. It would seem probable therefore that all the high water fluctuations depending on diurnal tide ought to be multiplied in a certain degree, in order to be comparable with those of low water. This would vitiate the determination of the epoch of high diurnal tide as compared with high semidiurnal tide.

Diurnal tide insensible at London.

(568.) At London there is scarcely a sensible diurnal tide in the height of high water. This might arise from the maximum and minimum stages of diurnal tide occurring very nearly at low waters (semidiurnal), the mean stages occurring at high waters; and this is partially supported by the observation that Mr. Lubbock has discovered traces of diurnal inequality in the times of high water at London, (*Philosophical Transactions*, 1837, page 120,) not however, in our judgment, very distinct. But (as will be seen in the chart of cotidal lines) there appears to be no doubt that the tide at London is produced by the mixture of two tides, one coming from the English Channel, and the other, which has been 12 hours longer on its way, coming from the North Sea; and that while the semidiurnal fluctuations of these, being in the same phase, corroborate each other, the diurnal waves, being in opposite phases, (high diurnal tide of one corresponding to low diurnal tide of the other, &c.,) destroy each other.

Instances of very great diurnal tides.

(569.) The equilibrium-theory (47.), and Laplace's theory (101.), lead us to expect that the diurnal tide will be large in middle latitudes, and small near the equator and near the poles. The theory of canals (440.) gives the same result, supposing the canal to be a complete circle passing through the poles; if the canal is incomplete or interrupted, considerations similar to those of (296.), &c. apply, and no simple law like that of (440.) can be enunciated. The fact of observation is, that the diurnal tide is as large near the equator as in middle latitudes, at least in some very remarkable instances pointed out by Mr. Whewell, and which have been made the subject of very careful examination (although the existence of very large diurnal tide, as the general law in those parts of the earth, may be ascertained at once from Romme or any other good account of tides). Near the equator are Singapore, King George's Sound, in lat. 35° S. (*Philosophical Transactions*, 1837), Coringa Bay, Cochin, Surat Roads, Gogah, Bassadore (*Philosophical Transactions*, 1839), and others less carefully observed. In the northern seas are Petropaulofsk (Kamschatka), and Sitkhi (Norfolk Sound). In some of these localities the diurnal tide, when its range is greatest, greatly exceeds the semidiurnal. Mr. Whewell appears to imagine that the actual tides cannot be completely represented by the combination of a diurnal and a semidiurnal tide; but, so far as we can perceive, there is no difficulty at all in thus representing them.

(570.) We cannot here enter into a consideration of all the various effects produced by the mixture of these tides in various proportions. But, for a general idea, we invite the reader's attention to figures 63, 64, 65. Fig. 63 represents the course of a fortnight's tides at Plymouth; and here the diurnal inequality, though sufficiently marked, does not conspicuously disturb the semidiurnal tides. Fig. 64 represents the course of several days' tides at Singapore, and fig. 65 that at Petropaulofsk. It will easily be perceived that at Petropaulofsk there appears to be but one tide in a day, sometimes because one of the semidiurnal high waters is made so low as to be little perceptible, but more remarkably at other times, because one of the semidiurnal low waters is made so high as scarcely to disturb the appearance of a single tide.

(571.) We here close our remarks on the discussion of "the laws of the tides for varying positions of the sun and moon" as ascertained from observation. And we cannot do so without formally pointing out to the reader that absolutely the whole of these, as regards the tracing out the laws of the phænomena, and very nearly the whole as regards the determination of constants and coefficients, is due to Mr. Lubbock and Mr. Whewell. Yet while acknowledging that nearly all that we know is due to these philosophers, we cannot help expressing our wish that they had taken as guide a more complete theory than the miserable equilibrium-theory, and for this reason—we believe that so we should have known much more. Where observations are so rude and so numerous that they can be treated only in large groups, every thing depends on the assumption of the theory which is to direct the selection of the groups. We cannot, however, be too grateful for so much which has been done well, and which must suggest so clearly the critical points that will demand special attention in future discussions of observations.

Effect of the barometrical pressure on the tides.

(572.) A circumstance affecting the height of the tides, to which we have hitherto made no allusion, is the state of atmospheric pressure. It was first pointed out (we believe) by the French hydrographer, M. Daussy, (*Connaissance des Temps*, 1834,) that a low state of the barometer is accompanied with high tides. This has been carefully examined by the English investigators, and M. Daussy's result is fully supported. On this point we cannot do better than refer the reader to Mr. Lubbock's paper, *Philosophical Transactions*, 1837, page 97, &c. It appears there that in a set of observations considered by Mr. Lubbock, the unexplained fluctuations of the tide correspond precisely to those of the barometer; and Mr. Lubbock has laid it down as a rule, that a rise of 1 inch in the barometer causes a depression in the height of high water amounting to 7 inches at London, and to 11 inches at Liverpool. Mr. Bunt also, in the *Eleventh Report of the British Association*, page 31, has discussed with great skill the effect of the barometer on the tides at Bristol, and has shown that a rise of 1 inch of barometer produces a depression of 13·4 inches. He has also shown that the height of the tide, as depending on the barometer, is properly to be computed with the *contemporaneous* barometer. The explanation of this circumstance, by considering that a heavy atmosphere acts as a weight pressing down the water, is plausible enough; but as we cannot conceive air of different pressures in different parts of the earth, without supposing that there is a violent effort to restore equality of pressures, we cannot say that it is quite satisfactory.

Sect. VII Compari son of Theory and Ob servatio of Tides. Subsec. On the Lawsof Tides fo varying sitions o the Sun and Mo

Effect of the wind on the tides.

(573.) Connected with this is the effect of wind upon the tides (as distinguished from barometric pressure). Both M. Daussy and Mr. Lubbock, on comparing the differences between observed heights and computed heights with the directions of the wind, have come to the conclusion that the effect of the wind is insensible; see *Philosophical Transactions*, 1831. Nevertheless all practical men believe that the wind has a considerable effect, different in different localities; the rule for London is given with great clearness by Mr. Lubbock in the *Philosophical Transactions*, 1834, page 145. In fig. 41 we have shown the effect at Sheerness of a single gale (January 3, 1841), which lowered the tides in the Thames five feet, as we ascertained from examination of the registers at St. Katharine's Docks, the London Docks, Deptford, Woolwich, and Sheerness; and which produced a depression of about three feet at Hull and at Dover, and a sensible effect at Bristol. At Dublin and at Glasgow the tides were raised by it. But the want of regular observation at any great number of ports has made it impossible to trace the course of this great depression in all the seas round Britain.

Subsection 4.—On the Progress of the Tide over different parts of the Ocean.

(574.) Our remarks on this subject will consist principally of observations on figure 66, the chart of the world with cotidal lines marked on it. It is almost entirely copied from Mr. Whewell's chart in the *Philosophical Transactions*, 1833, with some modifications suggested by his papers in the *Philosophical Transactions*, 1835 and 1836. The Roman numerals upon the cotidal lines denote the hour, in Greenwich time, of high water on the day of new moon or full moon, as far as can be judged from the various considerations collected by Mr. Whewell, principally in the *Philosophical Transactions*, 1833.

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(575.) The reader's first inquiry, on looking at this chart, will probably be, what are the extent and value of the evidence upon which these lines are traced? In a matter like this, depending entirely on numerous details, we can only, as a complete answer, refer to the original discussions, but we may here state our opinion very generally. The tidal hours on the coasts of Britain, Holland, France, Spain, Portugal, and North America, are now well known, from the simultaneous observations made at a great number of stations, for which we are entirely indebted to the zeal of Mr. Whewell, and to the liberality of the various governments to whom his representations were addressed. The tidal hours at the islands of the Atlantic appear also to be well known. We conceive therefore (recognizing also the justness of the principles on which Mr. Whewell has generally drawn his curves) that the cotidal lines of the Northern Atlantic are now drawn with very great accuracy. But when we remark the importance of the alterations which those simultaneous observations have introduced in the lines on the coast of North America, (although the evidence, upon which the first draft of those lines was made, was at least as good as that upon

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which the lines in other parts of the world are drawn,) and when we see the discordance of accounts as to the time of high water at many places, we cannot imagine that they are drawn with great certainty in other parts. Even the African side of the South Atlantic is not free from serious doubts, the Indian Sea is still less known, and for the Pacific Ocean east of New Zealand we have scarcely grounds for conjecture.

(576.) Taking them, however, in those parts in which they are best known, we may find many circumstances which admit of direct and instructive comparison with theory. In all places where the circumstances of depth, &c., vary much in a small extent of sea, we may consider the alteration in the tides through that extent as following simply the laws of waves on which no force is acting (because the length of the column of water on which the Sun or Moon acts is too small to allow their attraction sensibly to modify the pressures). Suppose now that in the neighbourhood of any particular coast the bottom shelves gradually from deep sea to one comparatively shallow. This would be attended, theoretically, with two consequences. The first is, that the wave would travel more slowly (174.), and therefore the separation of the cotidal lines corresponding to successive hours would be less, or the cotidal lines would appear to be crowded together on the map. The second is, that the magnitude of the tides would be much increased (247.), &c. And these circumstances might be found in places where the change in the depth was not known from observation; for the usual limit of sounding is 200 fathoms, which is probably a small quantity compared with the depth of the ocean. We may then expect that, where the cotidal lines approach closely, the magnitude of the tides will be increased. Now this does occur. A well-marked instance is the Bay of St. George in South America, in which a close approximation of cotidal lines is accompanied with large tides. It is possible here that the tides may be still further increased by the converging form of the waves (254.).

(577.) Another curious effect of the same cause is the distortion of the lines produced by islands, surrounded by shoals, in the ocean. The shoals prevent the tide-wave from advancing rapidly, and the cotidal line is therefore thrown back; but, conceiving the ridge of the wave to be thus bent, it is easy to imagine that after passing the island the two lateral parts of the wave will bend round it till they unite, and will then form a straight front nearly as before coming to the island. The successive cotidal lines will have forms corresponding to the forms of the ridge of this wave at successive times. Of this there are several instances apparently beyond doubt. Thus the 1 o'clock line is thrown back by the Azores; the 11 o'clock line is bent by the Bermudas, and its lateral branches nearly meet; the 10 o'clock line, after having been interrupted, just meets behind New Zealand. A similar effect of the same cause is, the universal dragging of the wave along the shore, as we have mentioned in (359.).

(578.) The velocity of the tide-wave ought, with the assistance of the table in article (174.), to give us good information as to the depth of the sea. Thus in the North Sea, figure 60, the tide-wave in 9 hours appears to describe somewhat less than 6 degrees of latitude, or, on the average, about 45 miles per hour. This, by the table in (174.), corresponds to a depth of 140 feet. We believe that the average depth along the line of deep channel is greater than this, and that at the sides less; and it is probable that the actual velocity is affected by both these. If the tide-wave of the Atlantic were purely derivative, it might be considered as describing 90 degrees of latitude, from the southern 1 o'clock line to the northern 1 o'clock line, in 12 hours, or to move about 520 miles per hour, which would imply a depth of about 18,000 feet or $3\frac{1}{2}$ miles. The reader will have no difficulty in extending similar remarks to other seas.

These remarks do not apply to large seas.

(579.) But these remarks apply *solely* on the supposition that the seas which are the subject of remark are so small, that the action of the Sun or Moon on a column of water as long as the sea will produce a pressure which is insignificant in proportion to the height of the tides or the changes in the heights. And this consideration, of which the justice is obvious, does, in our opinion, make it impossible to receive one of Mr. Whewell's speculations as to the tides of the Atlantic. The general course of the tide-wave there being from S. to N., or rather from SSE. to NNW., Mr. Whewell has inferred from this that the tides of the Atlantic are mainly of a derivative character, produced by the tides of the Southern Ocean and transmitted up the Atlantic in the same manner in which the tides of the Atlantic are transmitted up the English channel. We doubt this entirely. A channel as large as the Atlantic, if it ran due north, would have large tide-waves of a stationary character (440.) and (448.); but being in some degree inclined, the tide-waves would travel towards the NW. (439.) and (441.), but with a very irregular velocity, not dependent on the depth of the water (supposed uniform.) And even if the waves were stopped by a barrier (such as we may conceive the coast of North America to be, omitting the comparatively narrow channel between Britain and Greenland), yet the investigation of (838.) shows that the effect of friction is to give nearly the same formula for the tides in mid-sea as if no barrier existed. Indeed we may remark as the general effect of friction, that the tides at a distance from shore, or at a distance from a communicating channel, will depend more, so far as regards their form and succession, on the acting external forces than on reflection from barriers or communication from other seas, their magnitudes, however, being diminished and their epochs being altered. Without, therefore, denying entirely the effect of the Southern Sea, we conceive it to be extremely small.

The tides of the Atlantic cannot be treated as derivative tides.

Difficulty of explaining theoretically the transmission of tide-wave in the Atlantic.

(580.) But, whatever supposition we make as to effects of friction, &c., the power of mathematics fails totally in the attempt to express the transmission of the tide-wave or waves through the Atlantic Ocean. It has some analogy to a canal, (an analogy which, though distant, gives us confidence in applying some of the results deduced from canal investigations, as for instance the effect of the depth on the magnitude of the tide, and the effect of friction in producing the age of the tide.) But it has not so much as to enable us to predict what will become of the tide-wave in its general progress; and of course the analogy fails totally as regards the effect of those very important features which have no existence in a canal; huge promontories projecting into its sides, or vast bays opening large lateral expanses for the spread of the tide-wave.

(581.) There is moreover another consideration which must not be left out of sight in estimating the difficulty of reconciling our observations of the tides of an ocean with such a theory as we are able to give even for the simplest cases. It is that, supposing the cotidal lines to be accurately what they profess to be, namely, the lines connecting all the points at which high water is simultaneous, we have nevertheless, in (366.), &c., given reasons for supposing that they may not at all represent the ridges of the tide-waves that run over the ocean. Thus, an eye at a great distance, capable of observing the swells of the tide-waves, might see one huge longitudinal ridge extending from the mouth of the Amazons to the sea beyond Iceland, making high water at one time from Cape de Verde to the North Cape, and at another time from Florida to Greenland; and another ridge, transversal to the former, travelling from the coast of Guiana to the northern sea; and the cotidal lines which we have traced may depend simply on the combination of these waves. It does not appear likely that we can ever ascertain whether it is so or not; but it is certainly possible that the original waves may have these or similar forms; and if so, it is vain for us to attempt entirely to explain the tides of the Atlantic.

The cotidal lines may not represent the ridges of the tide-waves.

The interference of wave-ridges may explain the cotidal lines west of America.

(582.) To the Pacific Ocean the same remark applies still more strongly. There is however one part in which we seem to discover, from the considerations mentioned above, some explanation of the singular form of the curves as traced by Mr. Whewell; namely, the western coast of South and Central America. It seems not unlikely that the east-and-west action of the tidal forces, acting as if on the water in canals stretching east-and-west, would produce waves running east-and-west, (the length of their ridges being north-and-south,) according to the laws of (296.) and (337.). It seems probable also that the north-and-south action of the tidal forces would produce another wave, either running north or south, or of stationary character. The effect of the composition of these, as in (366.), &c., would be to produce cotidal lines, having considerable resemblance to those on the American shore of the Pacific.

Difficulty of explaining the diurnal tides in the Pacific.

(583.) If we look to the Pacific Ocean with reference to diurnal tides, and consider the southern sea as a part of it, we seem to have a case which possesses considerable analogy with Laplace's assumption. Yet it is remarkable that here we appear to find a more complete failure than anywhere else, of Laplace's celebrated result as to the non-existence of diurnal tide, (all the large diurnal tides being in that sea.) It is true that this failure might be explained by supposing the depth of the sea to be extremely unequal.

(584.) Upon the whole, therefore, we are driven to the conclusion, that we cannot at all explain the cause of the form of the cotidal lines in the ocean, so far as they have been traced with any probability. And, supposing us to know with tolerable certainty those corresponding to the semidiurnal tide, we cannot at all predict those which should hold for the diurnal tide.

Laws which nevertheless will apply everywhere.

(585.) Nevertheless we are able to lay down one law of vast theoretical importance, (or rather two laws, one applying to the group of semidiurnal tides and the other to the group of diurnal tides.) It is simply that assumed by Laplace, and which also applies to, or includes the effect of, our theories of "the relation of the magnitude of the tide to the depth of the water" and "friction." Whatever be the number of communications from other seas, or reflections from barriers, whatever the depth of the water or the amount of friction, still the result of a given periodical force will be a periodical effect whose period is the same, but whose coefficient is represented by the coefficient of the force multiplied by a function of the period, and whose argument also contains a term which is a function of the period. This law completely brings under our management all terms depending on the slow variation of forces (as those which depend on ellipticity, declination, &c.) For $(1+3e\cos ht)\cos nt$ is

$$=\cos nt+\frac{3e}{2}\cos(n+h)t+\frac{3e}{2}\cos(n-h)t,$$

and, h being small, either of the functions of n mentioned above, and which we will call N, is changed for the additional terms to $\mathrm{N}+\frac{d\mathrm{N}}{dn}h$ and $\mathrm{N}-\frac{d\mathrm{N}}{dn}h$; and, $\frac{d\mathrm{N}}{dn}$ being discovered in any one case, (as, for instance, when Laplace inferred it from the observed declination-correction,) is applicable to the other cases, (as, for instance, when Laplace applied the value so found to correct the first value of the mass of the Moon.) And this holds for any port under any circumstances whatever; it even holds, so far as we can see, for the heights of tide as distinguished from the time of tide; and from these two classes of phænomena (supposing observation to be perfect) the correct mass of the Moon ought equally to be inferred, though the laws of the two classes are, in the first inspection, discordant. But this law does not in the same manner bring under our management the rules of diurnal tides to be inferred from semidiurnal, or *vice versâ;* the difference between n and $2n$ being too great to permit us to confine ourselves to the two first terms of Taylor's theorem. A similar law however would connect the diurnal tide with the slow variations of diurnal tide and the alteration to be made in the Moon's mass as applying to diurnal tide; and thus, theoretically speaking, the Moon's mass might be inferred from the parallax-corrections of diurnal tides in the same manner in which Laplace has found it from declination-corrections of semidiurnal tide.

CONCLUSION.—ON THE PRESENT DESIDERATA IN THE THEORY AND OBSERVATIONS OF TIDES.

(586.) If we advert to the different parts of this extensive subject in the same order in which we have treated them in the preceding Essay, we shall find the following to be the most important points requiring attention.

(587.) A subject of very great importance is, the more general solution of Laplace's equation in (96.), to the extent mentioned in (119.), so as to enable us to apply the general theory to seas limited by shore-boundaries. A great point would be gained if this could be done on any assumption whatever as to the depth of the sea.

(588.) The value of Laplace's theory is lost in a great measure, because the solutions hitherto attempted apply only to those cases in which $i=n$ exactly (100.), or $i=2n$ exactly (107.). Thus the difference in the specific action of the Sun and Moon, depending on the difference of their angular velocities, is entirely lost. It would be highly important to obtain solutions on the supposition, that i differs from n or from $2n$ by a small quantity whose square may be neglected.

(589.) Laplace's theory would be much more valuable if it were extended so far as to include the effects of friction. The methods of (315.), &c., would probably apply with sufficient accuracy.

(590.) The additions to the theory, indicated in the three last articles, would be exceedingly valuable, even if quite independent. If they could be treated in combination, their value would be very greatly increased.

(591.) In the theory of waves, the most important point by far is the theory of river-tides, in which the extent of vertical oscillation bears a sensible proportion to the depth; which we have partially treated in (192.), &c. The following extensions would very much increase its value; it is apprehended that they would introduce more of labour than of difficulty.

(592.) The investigations of (218.) and (260.) must be extended so as to include the terms depending on the vertical oscillation, at least to the third order; observations showing that those terms are not only sensible but important. This investigation, if properly conducted, will include the extension of the investigation of (309.).

(593.) The effect of friction must be introduced in combination with these investigations.

(594.) The investigation must, if possible, be effected for the case where the vertical oscillation is very great; as, for instance, where the low water leaves very small depth on the bottom. In this case it is hopeless to attempt a converging series, and an independent and finite method must be tried. Much would be gained if this could be effected in the simplest case, as for a rectangular channel, of uniform section, without friction.

(595.) In regard to observations, it is very desirable that simultaneous observations at short intervals should be made on different points of some long tidal river, or some deep estuary, for examination of the change of the wave. These observations should be discussed as is mentioned in (479.). It is particularly desirable that these observations should be made in very high spring tides and in very low neap tides, to discover the laws of alteration of the various constants as depending on the range of the tide.

(596.) As a special locality, we may point out the various channels near the Isle of Wight as most particularly requiring attention. It would be very useful that simultaneous observations of a few tides should be made at two or more points on Southampton water, two or more on the Solent, one or two on the eastern side, as at and beyond Portsmouth, and one or two on the west side of Hurst Point.

(597.) In regard to the reduction of long series of tide-observations as applicable to particular ports, we shall only call the reader's attention to the following points.

(598.) It will probably be found, from the inquiries, theoretical and experimental, to which we have alluded above, that the elevation of high water in rivers or bays requires a certain multiplier to make its fluctuation of range comparable proportionably with the fluctuation of range on the coast, and that the depression of low water in like manner requires a multiplier different from the former. Much confusion would be removed by ascertaining these multipliers and applying them at once to the observations.

Tides and Waves.

Correction of time, depending on range of tide.

(599.) It will probably also be found that the time of high water requires a correction depending on the whole vertical range, to make it comparable with that of the sea; and that the time of low water requires a different correction. These should be ascertained, if possible, and applied. It would, perhaps, be best to assume that such a correction is needed, and to determine its quantity from the observations themselves in such a manner that the epochs of highest tides and mean lunitidal intervals shall synchronize. And in like manner, for the corrections to the heights, it might be best to determine the factors, so that the mean height shall be uniform, and that the first proportion of the Moon's mass to the Sun's, inferred from the semimenstrual inequality of heights, shall be the same as that given by the semimenstrual inequality of times.

Correction of height.

Methods for diurnal tide.

(600.) In the places where the diurnal tide, though sensible, is small, its effect in height at the time of high or low water may be considered independent of its effect on the time of the high or low water, and *vice versâ*. The best way of disengaging it, numerically, would probably be, to calculate a small approximate table of second differences of the heights, and, subtracting from each observation of height the mean of the preceding and following heights, to apply that computed second difference. But where the diurnal tide is very large, the effect on height is not independent of the effect on time. In this case we see no method so clear and easy as to calculate beforehand a few tables of the values of $\cos\theta + a\cos(2\theta + b)$ with different values of a and b; the result will enable the experimenter to judge how much the real epoch of high semidiurnal tide differs from the time of highest water, and what is the real epoch of diurnal tide. The same will apply to the times.

Methods for general inequalities.

(601.) The whole of the inequalities should then be treated with reference to the theory of (451.), and so as to include the terms pointed out in (550.) and (554.). For these it will not be sufficient to class together all observations at which the declination was the same; before this is done, the whole must be divided into two categories, namely, those of declinations increasing and of declinations diminishing, which are to be afterwards subdivided by absolute declinations. In like manner, as regards parallax, all the observations must be divided into the two categories of parallax increasing and parallax diminishing; which are to be afterwards subdivided by absolute parallax. The whole of these elements are to be taken for an epoch anterior by a quantity equal to the age of the tide. From the discussion of these inequalities in time as well as in height, the mass of the Moon is to be inferred by the process sketched in (555.); and the agreement of the different values of the mass will be the proof of agreement of theory and observation.

(602.) The best method of starting in these reductions cannot be the subject of general rule; the age of the tide however should be determined as early as possible. When the lunar parallax correction is ascertained, that part of it which applies uniformly in the same age of the Moon (depending on variation) should be subtracted from all the observations, or rather from the means of the groups, and then only can the semimenstrual inequality be found exactly. Each inequality, when determined, should be subtracted from the observations before investigating a new one.

(603.) The same methods should be used for diurnal inequality, where it is conspicuous. But, as north declinations and south declinations are not now to be confounded, it will be advantageous to express the places of the Sun and Moon by north-polar-distances instead of declinations.

Points to be noticed in the tide-observations in the Pacific Ocean.

(604.) In regard to the tracing of cotidal lines, the principal defect, in marine localities which otherwise are well known, is in the Pacific Ocean generally. The attention of those who are interested in defining these lines should be particularly directed to the devising of means for rendering the tide even coarsely sensible, in places where its range is small, where it is partly masked by day-breezes and night-breezes, and where the water is held in a state somewhat different from that of the open sea by the rings of coral reef which surround so many of the islands.

Conclusion.

Referen to the si plest fu of tide-function for dra ing coti lines.

(605.) In some smaller seas scrupulous attention should also be given to the distinction between the actual time of high water and the time when the simple sine expressing the sea-tide reaches its maximum. It is not unlikely that in this way some part of an apparent anomaly which Mr. Whewell has remarked to the east of the Isle of Wight may be removed.

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ARCHITECTURE.

PART I.

THE ANCIENT ARCHITECTURE OF GREECE, EGYPT, AND PERSIA.

CHAPTER I.

The Origin of Architecture.

practice building gan with first So-ties.

If we pass over the time when there existed no implement capable of excavating a rock, or felling a tree, and when the human savage, who drew his subsistence from the Earth or waters, retired for the night to the shelter of some natural cave or hollow tree, we shall come to a period when the practice of building began in the World, and this was, probably, as early as the formation of the first Societies. As soon as a number of individuals or families had united themselves together for the purposes of defence, or of more effectually obtaining the means of support, habitations, larger and more commodious than those afforded by Nature, would be required.

The means resorted to by different Tribes of people to procure the necessary protection from the inclemency of the weather, may be reasonably supposed to vary according to the mode by which each people obtained its subsistence, to the materials for building which happened to be found in the places occupied, and, perhaps, to some peculiarities of character with which each people might be endowed.

ts and es were bably the habita-ns.

A pastoral nation, of which each family must change its place of abode as often as its flocks consume the productions of the Earth about the station it occupies, will have little inducement to erect permanent buildings; and, in a region nearly level, tents, or at most, light timber-huts, which can either be removed at pleasure, or abandoned without loss, will, probably, be the only dwellings it finds necessary to construct.

Nearly the same thing may be said of a people inhabiting a mountainous country, or the sea-coast, and seeking its support from hunting or fishing; for the families or communities which pursue those modes of living, being thinly scattered over an extensive territory, will, in most cases, find it convenient to fix their abodes in caves formed by Nature or Art in the rocks.

what cir-stances might be-an Art.

But when men applied themselves to the cultivation of the ground, in a region where an ungrateful soil compelled them to the constant performance of a regular succession of labours in order to acquire the means of subsistence, being necessarily attached to one spot, perhaps for life, it is conceivable that their dwellings would be of a permanent nature; and, consequently, it is among such a people that, through successive improvements, the practice of building may be expected to rise to the dignity of an Art. This would take place when, in process of time, men had learned to give to their buildings such internal arrangements as were suited to the purpose for which they were intended; to make the exterior forms characteristic of those purposes; and to establish the fit proportions which the several parts of an edifice should bear to each other, in order to fulfil the above conditions, and to render the whole capable of producing an effect which might be pleasing to the eye. Now the Art of Architecture is a collection of rules for constructing buildings conformably to these principles.

The prototype of Architectural works unknown.

As this Art must have had its origin in some very simple and rude construction, and as its early progress must have been made by insensible steps, neither the primitive form of a building nor the successive improvements it underwent were likely to excite such notice at the time they were made, as to cause the memory of them to be preserved. It is therefore hardly to be expected that any Tradition, still less that any Historical document should remain, concerning either the one or the other, of a date anterior to the establishment of a considerable number of general principles of construction. Afterwards, these becoming objects of study for persons who were called upon to exercise Architecture as a profession, would necessarily lead to an inquiry whether they were founded upon any original model, and what that model might have been.

Probable form of the first houses.

Vitruvius, who wrote on the Art, in the time of Augustus, or of one of his immediate successors, has, in the Ist Chapter of his IId Book, indulged his own fancy, or recorded that of some more ancient Philosopher, respecting the origin of the Arts and Sciences, and particularly that of the Art of building. Having given a fabulous account of the origin of fire, he goes on to state that, by the comfort men derived from it, they were induced to form themselves into Societies, and erect buildings to shelter themselves from the severity of the climate. Such buildings, he thinks, would resemble the huts constructed by men who occupy the lowest grade in Society; and, to give an idea of that primitive style, he describes the mode of building practised by the Colchians, a people who probably were then in the same rude state as are now the inhabitants of the Islands in the South Seas.

He says, it consisted in fixing trees upright in the ground, side by side, so as to include the space to be inhabited; the distance between the rows of trees equalling the length of the trees intended for the covering. The roof was laid over the tops of the upright trees, and above these, other upright trees were placed, in a manner similar to those below. Thus the building was raised to the height required. A roof was formed at the top, he says, by raising beams across from the four angles, so as to unite in a point; the sides and roof were filled up with boughs, and the interstices were stopped by chips and clay.

It is, however, by no means necessary to suppose that the square or rectangular form which Vitruvius describes is the only one which would be affected by the earliest people for their houses; indeed, it is probable that a circular form would as often be adopted, if it were not the original construction; and this is so much the more likely to be the case as it is less artificial, and as the practice exists among those people who approach the nearest to the state of Nature. The conical form is that which is actually given to their huts by the natives of the Southern extremity of the American Continent, and a cylindrical form of wall with a conical roof is very generally adopted in the interior of Africa.

Tombs of masonry are probably more ancient than dwellings of the same material.

The inquiry into the nature of the earliest edifices seems to lead us to the discovery that, before Man had provided any thing better than a frail tenement of wood to shelter him, when living, from the summer's heat and winter's cold, he had bestowed incredible pains in the endeavour to form an eternal building of stone which was to receive him when dead.

A pile of stones, or a mound of earth, was certainly the first monument erected to commemorate some event, to mark the grave of some person who had been of importance during his life, or to serve as a general receptacle for the bodies of men slain in battle: such are the monumental Barrows of earth or stones which abound in Europe, from the Steppes of Tartary to the Highlands of Scotland, and which have been discovered even in North America. The more artificial Pyramids, which have been erected in so many different parts of the World, are works, in all probability, intended for similar purposes, and their construction displays the next step in the Art of building.

Origin of the pyramidal form of tombs.

The pyramidal or conical form, which was universally given to these monumental masses, is naturally enough derived from the form which earth assumes when thrown loosely in a heap, such as that which would necessarily be made over a grave when the excavation was filled up after the body had been deposited; or, we may add, from the form assumed by stones piled loosely on the ground as a monumental mark; and, accordingly, we may consider the adoption of that form as an argument in favour of the propensity of Man to imitate, in his artificial constructions, the appearance of some natural object, or some primitive work.

Tombs excavated in rocks.

In Countries abounding with mountains and rocks, natural excavations would often be found capable of serving as receptacles for the dead; and when these were wanting, artificial excavations might be made with less labour than it would require to erect a Pyramid. It is therefore probable that both these species of sepulchre are of equal antiquity, and were employed for the same purpose, according to circumstances. Excavations, which have been used as sepulchres, abound in Egypt, Persia, India, and Europe, and even in the Island of Teneriffe in the Atlantic Ocean. An account of the disposition of the chambers and galleries in the principal places where such sepulchres have been formed, is given under CATACOMB, in our *Miscellaneous Division*.

Pyramids and caverns were probably used also for other purposes.

But though the Pyramids and Catacombs were, generally speaking, intended to contain the bodies of the dead, there is sufficient reason to believe that in some cases they must have been used as Temples, or at least, that some part of each was appropriated to the purposes of Religion, or to the residence of its Ministers; the latter destination is inferred from the testimony of Herodotus, who on that account was not permitted to see the interior of the Labyrinth in Egypt. It is possible also that such works may have occasionally served as retreats for the inhabitants of a Country from the pursuit of an invading enemy, or as secure places to contain the treasures of the Sovereign or of the State. For some or all of these purposes, Pyramids or caverns seem to have been the necessary accompaniments of most cities of the ancient World.

Egypti Pyrami

At the earliest period of Society in Egypt, the rocks of Thebais seem to have presented an indestructible asylum for the dead, who were deposited in extensive excavations made in those natural masses of stone; but when the seat of the Empire was removed to Memphis, near the Delta, those masses were not so abundant, and it became necessary to erect artificial buildings, containing chambers for the same purposes; such masses are the Pyramids, which still exist in that part of the Country, and form a distinguished feature in an Egyptian scene.

The three principal Pyramids of Egypt are supposed to have been erected by Cheops, by his brother Cephrenes, and his son Mycerinus, who were successively Kings of that Country. But so little dependence can be placed upon the early History of Egypt that it is impossible to say whether we are to refer their reigns to a period previous or posterior to that of the Trojan war. Those Pyramids are situated along the Nile, near Cairo, probably not far from the place where the ancient Memphis once stood, and they are built of granite upon a nucleus of natural sandstone.

At a short distance Southward from the great Pyramids is the town of Saccara, in the neighbourhood of which are several Pyramids, some constructed of stone, others of brick, and one is described as formed of heaps of pebble-stones cemented together. The exterior of the latter is composed of six stages, each terminating at top in a horizontal surface 11 feet broad, and the vertical distance from stage to stage is 25 feet. Between the stages, the faces of the Pyramid are oblique to the horizon, so that the whole has the appearance of several frusta of Pyramids placed one on another.

In Upper Egypt the Pyramids seem to have been less general than in the country about Cairo, probably because the natural rocks were more abundant in the former district than in the latter; but M. Caillaud, and subsequently Mr. Burckhardt, observed great numbers in Nubia, at the distance of more than one hundred leagues beyond the cataracts of the Nile. They are described as bearing considerable resemblance to those of Egypt, both in their general form and in the character of their sculpture, but they are much smaller, the greatest not being above 50 feet high. They are disposed in groups of twelve or fifteen together, and within the mass of each is formed a sepulchral chamber, to which there is an entrance through a Temple built against the face of the Pyramid.

Anci Pyra of As

The custom of erecting Pyramids must have been very general throughout Asia. The Tower of Babel was, not improbably, a work of a similar nature, and that which was called the Tower of Jupiter Belus, in the centre of one of the divisions of Babylon, was certainly so. According to the description given by Herodotus, (*Clio*, sect. 181.) the base of this Tower was a square, each side of which was a furlong in extent. The building consisted of eight different portions in pyramidal forms, one above another; the whole height was one furlong, and as the portions are stated to have been built in regular succession, perhaps they were all of equal height, *viz.* about 80 feet. The ascent from the ground was by an inclined plane which passed eight times about the Tower, and formed the divisions just mentioned; in each of the divisions were constructed Temples, consisting of apartments whose roofs were supported by pillars, and in the upper Temple was a magnificent couch of gold. It is probable also, that this Temple was used as an Observatory, and that from it the Chaldean Astronomers made the celestial observations, of which a few have been transmitted to our times. Here, then, we have an example of a Pyramid which does not seem to have been used as a tomb.

In his account of the Retreat of the Ten thousand Greeks from Persia, Xenophon mentions the arrival of his army at an uninhabited city, which he calls Larissa, situated on the Tigris; and he says, that close to the city there stood a Pyramid of stone, 100 feet square and 200 feet high, into which the inhabitants of the neighbouring villages retired after the defeat of the Persians. (*Anabasis*, book iii.) Bochart supposes this city to be the Resen stated by Moses (*Gen.* x. 12.) to have been built by Ashur; and if so, there is a probability that this Pyramid was one of the most ancient in the World. It seems to have contained chambers, and therefore must have been intended either for a tomb like those of Egypt, or for a place of worship, like the Tower of Belus. Its proportions, however, differ considerably from those of the Egyptian Pyramids, inasmuch as its height appears to have been double the length of each side of its base, whereas the heights of the latter are scarcely equal to the lengths of their sides.

is of

In the earliest times, Barrows of a conical or pyramidal form seem to have been commonly raised as funereal monuments in Greece. In the XXIIId Book of the *Iliad*, Homer states that the Tomb of Patroclus was made by heaping earth over his grave; and, from the circumstance that the foundations are said to have been laid deep, we infer that the Pyramid was reveted with masonry. Pausanias mentions (*Argolica*, c. 15.) a sepulchre of Opheltes, at Nemea, about which were several altars, and the whole of which was surrounded by a stone wall; and he speaks of a pyramidal structure between Argos and Epidauros which was built over the graves of the combatants who fell in the quarrel of Prætus and Acrisius. These monuments, perhaps, resembled that pyramidal Tower which still exists near Argos, on the road to Tripolizza, and which is described in the *Supplement to the Antiquities of Athens* originally published by Stuart and Revett. Its plan is rectangular; at the foot the length is 44 feet, and breadth 31 feet 4 inches; the height of the part yet standing is 9 feet 2 inches, and at that level the length is 34 feet, and breadth 24 feet 3 inches. How the building was terminated above is unknown, all the upper part having been destroyed, but in the interior there is a chamber, now roofless, about 20 feet long and 17 feet 6 inches wide. On one face of the Pyramid is an entrance covered by horizontal courses of stones which project beyond each other till they meet at top, and form a triangular head. A passage from this entrance leads nearly to the opposite face of the Pyramid, and at the extremity on one side has been the doorway of the apartment.

It is a remarkable circumstance that Pyramids did not, subsequently, become prominent objects in Greece, as they did in Egypt, and perhaps we may consider this as a proof of the independent origin of the Architecture of the former Country; the prevalence of a more complex and refined style of building, in later times, probably caused simple Pyramids to be disregarded, and such as once existed to be destroyed.

Pyramids are not confined to the ancient continent.

The pyramidal form of Sepulchral monuments, or Religious edifices, does not appear to have been confined to the ancient continent; we find the same form affected by the inhabitants of parts of the World which are separated from it, in opposite directions, by the Atlantic and Indian Oceans: we allude to the Pyramids existing in Mexico at the time of the invasion of that Country by the Spaniards, and in the Islands of the South Seas at the time of their discovery, and perhaps at the present day. On reading the descriptions of these works we cannot avoid being struck with their resemblance to the Pyramids of the Babylonians and Egyptians.

Dr. Robertson states, on the authority of the Spanish writers, in the VIIth Book of his *History of America*, that the great Temple of Mexico was a solid mass of earth, of a square form, and having part of its superficies reveted with stone. Each side of the base was 90 feet long, and it diminished gradually upward till it terminated in a quadrangle 30 feet long each way; on the top of this square was a Temple containing two altars, on which the victims were sacrificed. And he thinks it probable that all the other Temples of Mexico resembled this exactly. Whether it was intended as a place of burial, or not, does not appear, but the *morai* which Captain Cook saw at Taheite in his first voyage was certainly an elevation for that purpose. He says it consists of an enormous pile of stonework 270 feet long, 90 feet wide, and from 40 to 50 feet high, in the form of a Pyramid, with a flight of steps on each side. The foundation consists of rock stones, the steps are of coral, and the upper part of round pebbles; the rock and coral stones are squared neatly, and the whole is compact and firm, which, considering it was constructed before the natives possessed iron tools, or cement, must have been a work of prodigious labour. This forms one side of a court, whose length and breadth are nearly equal, and the court, which is surrounded by a wall, is paved with flat stones.

Having described what are the most simple constructions, and what were the kind of works first executed by Man, we proceed to exhibit the probable origin of edifices of a more artificial character.

CHAPTER II.

The supposed Prototype of a Systematic Style of Building.

Comparison of an original hut of timber with the form of an ancient Temple.

We may collect from what is said by Vitruvius in the IId Chapter of his IVth Book, that, at a period as early as his time, the analysis of the forms of buildings had led to the hypothesis that they are all derived from some mode of construction employed in the infancy of Society; and consequently that the most superb edifices are but grand imitations of the system of timbers forming the framework of a simple cottage. It is indeed easy to conceive that whatever might be the forms of the primitive dwellings of the inhabitants of any Country, that form would be copied when a more substantial material than timber was employed, or a more extensive edifice than a hut was to be constructed. If, then, we admit that the first habitations of any people were of timber, and in whatever Country this material abounds it is probable enough that such would be the case, the hypothesis will be justified by showing the correspondence between the construction of a timber-hut and the general disposition of the members of a stone edifice, which may be supposed to have been erected by the people of such a Country at a time when the Arts and Sciences were extensively cultivated among them.

This conformity we purpose now to trace, taking for our example a building similar to some of those erected in Greece or Rome at the time of its greatest national splendour. Such a comparison will afford an opportunity of showing the situations and uses of the principal members which enter into the composition of almost every building of importance, whether ancient or modern, and, therefore, will facilitate the comprehension of the more particular descriptions which will be, hereafter, given.

It may first, however, be observed that Architecture was, probably, brought to considerable perfection in edifices of timber before stone was employed; because no traces remain of any buildings, executed in the latter material, whose forms indicate a series of approximations to the perfect state of the systems or Orders exhibited in the most ancient of the existing edifices; and it cannot be said that such examples may have formerly existed but are now destroyed, because it is reasonable to believe that such works, being the oldest and rudest, would be constructed in a more substantial manner than the others; and, therefore, would be better able to resist the ravages of time.

The best notion we can form of the construction of the hut is, that a number of posts would be placed vertically on the ground, so as to enclose an area in the form of a square or parallelogram; along the tops of these would be placed a horizontal beam on each of the four sides, and over these would be laid other horizontal beams, parallel to one of the sides of the building, in order to support the material which was to serve for the roof. But, as the flat covering which we have here supposed, would not, in a Country subject to heavy rains and snows, afford a sufficient protection to the interior, an inclining roof supported by beams placed obliquely above the vertical posts would, very early, be substituted for the flat one. Now the Temples of the Greeks and Romans were generally rectangular, accompanied and, often, surrounded by columns, and covered by roofs inclining on both sides from a ridge over the middle of the building and parallel to its length. This construction bears, certainly, great resemblance to the hut just described; but, in order to get a more complete idea of the correspondence of the copy with its supposed original, we must compare them together more particularly, first exhibiting the principal members and, afterwards, the minor parts in detail.

The origin of the columns and entablature.

The trunks of trees placed vertically in the ground are supposed to be represented by the columns in the finished building. (Pl. i. fig. 1.) Over the tops of these trunks, on each face of the primitive hut, was placed a beam horizontally, and this, in the copy, is what has the name of *epistylium* or *architrave*. Above the architrave may be supposed to come the transtra or horizontal timbers, which, stretching over the enclosed space, in a direction parallel to either face of the building, support the roof. These being placed at certain distances from each other, and their extremities appearing immediately over the face of the architrave, were represented in the copy by rectangular divisions which, from the manner of ornamenting them, bear the name of *triglyphs*. The notches cut in the architrave to receive the extremities of those beams were called by the Greeks *opæ*, and, hence, the intervals of the beams have the name of *metopes*. The whole space occupied by the triglyphs and metopes was called, by the same people, *zophorus*: in later times it has been called the *frize*, because it is generally ornamented with sculpture.

From this description of the timbers above the architrave, it will be immediately perceived that the triglyphs, which represent the extremities of those timbers, should only appear on two opposite faces of the building; yet, in every ancient example of a rectangular building where triglyphs are employed, they are formed in a similar manner on each of the four faces; unless, therefore, we suppose the timbers to be disposed in two directions, at right angles to each other, and to be framed together so that the lower and upper surfaces may be in the same plane respectively, this must be considered as a departure from strict conformity with the original model; and then the triglyphs placed on the two faces which are parallel to the directions of the beams must be supposed to have been intended, only, to give a certain similarity of ornament to all the fronts of the edifice. It is not, however, in every building that a representation is made of the ends of the beams immediately above the architrave; for, in some, the frize is ornamented in a different manner, or left quite plain, as if copied from a model in which the ends of those beams were covered by a smooth board.

Above these transverse beams may be supposed to have been placed other horizontal beams of smaller dimensions, closer together, and at right angles to them. The extremities of these latter beams, or joists, may extend beyond the face of the architrave and frize and support the planks or still smaller timbers, which either constitute the covering itself of the roof, or serve as a bed for the materials employed for the covering. The reason of extending the joists and covering of the roof beyond the face of the architrave, is, that the rain-water which falls on the roof, may, thereby, be thrown beyond the posts or columns, or beyond the walls of the building, if, in the intervals of the posts, walls are constructed. The projecting parts of the lower joists just mentioned, being imitated in stone buildings executed according to some of the systems or Orders, become what are called *modillons*, and the extremities of the upper course represent, perhaps, what are called *dentels*. Each of these species of projections, like the triglyphs, can, properly speaking, only appear on two fronts of any quadrangular building, unless each course consists of timbers framed at right angles to each other, as above described; but as this method is not adopted in practice, and as we find that the modillons and dentels are exhibited on every face of such buildings, we must suppose this to be a measure adopted, as before, for the sake of obtaining a similarity of ornament on every side.

The courses of modillons and dentels, together with the beams upon which those courses appear to rest, and the part of the roof above them, form what was sometimes, by the Ancients, called the *corona*, but, in modern Architecture, is called the *cornice;* and the name of corona is occasionally by Vitruvius, and always by the moderns, confined to the projecting member immediately above the modillons. The whole system of horizontal beams above the columns, comprehending the architrave, frize, and cornice, was called by the general name of *epistylium*, but in later times, the *entablature.*

When an inclining roof was to be made, (see pl. i. fig. 2.) beams, called by Vitruvius *cantherii*, and by the present Architects, *rafters*, were disposed in two planes declining each way from the columen, or ridge of the roof, which ridge extended longitudinally above the middle of the area enclosed by the building: the upper extremities of the rafters were attached to this ridge, and the lower extremities rested upon the entablature vertically over the extremities of the horizontal beams in the frize. Above these rafters were placed small timbers, called by Vitruvius *templa*, by the moderns *purlines*, in horizontal positions, and parallel to the ridge of the roof; and, over them, a second tier of rafters, smaller than the former, and projecting, at their lower extremities, beyond the face of the architrave or frize on the flanks of the building. These last rafters, in some cases, carry the tiles or other materials which cover the sloping roof; and if we may suppose them to be placed so that one rafter may be over each triglyph and metope, the projecting extremities, being imitated in the copy, will constitute what, in one of the Orders, are called *mutules*, whose inferior surfaces are in a plane parallel to the inclining surface of the roof in which they are placed. And though these also can only, with propriety, exist upon the two lateral fronts of any building, yet it has been, universally, the practice to depart so far from the model as to repeat them upon the front and rear faces of a complete edifice. The extremities of the purlines, appearing in front and rear of a building, may have suggested the idea of forming modillons in each of the inclining sides of the roof, which in some of the Orders is done; but, in practice, a deviation is made from the character of the model by placing such modillons closer together than the purlines really would be, and by forming their side faces in vertical planes instead of perpendicular to the directions of the rafters.

The desire of ornamenting the inclining extremities of the roof in a manner similar to the horizontal cornice has led, in some Orders, to the employment of dentels also in those situations; as if the inclining roof had been formed by two tiers of purlines, in alternate order with the rafters, under its external covering.

In the above developement of the Vitruvian hypothesis, it is not intended to assert that artists can, in any case, bind themselves to produce a perfect correspondence of all the members in the buildings they construct, with those of any model; but, merely, to exhibit a simple structure, the parts of which may have served as prototypes of the members we find occasionally employed in the most complex edifices.

The roof of a building, when formed by two inclined planes, was, by the Ancients, called by the general name *fastigium*. The triangular extremity of such a roof is called a *pediment*, and the space included within the horizontal and inclined cornices of the pediment had, and still retains, the name of *tympanum.*

The principal members of a finished edifice have now been compared with those of the simple hut; if we descend to the minuter parts and ornaments, we shall find that many of them may be traced to objects necessarily connected with the same prototype, and from which it is possible they may have been derived; others, by their nature, are incompatible with such an origin, and, therefore, must be considered either as imitations of some natural objects, or as improvements which would easily suggest themselves when the members were executed in a different material.

The base of a column.

It is supposed that, originally, the trunks of trees, which served as posts, might have been planted immediately upon the ground; but experience would soon show that the bottoms of the posts were liable to be destroyed by its humidity, or that the weight of the edifice would force them into it, and thus endanger the safety of the whole. An endeavour would, perhaps, be made to remedy these evils, by placing a tile or flat stone under the bottom of the post to keep it from the ground, and, by presenting a greater surface underneath, to prevent it from sinking; from this probably originated what has been since called the *plinth.* The bottom of the post being liable to split by the weight above it, may be supposed to have been protected by a hoop or cord surrounding it; and, from this, some have derived the torus and other ornaments placed above the plinth, which, with the latter, form the *base* of the column.

The capital.

Now it might happen that the tops of the posts were not exactly situated in a horizontal plane, from the inequality of the ground, or of the lengths of the posts; and, in such a case, the architrave which was placed upon them, might not touch every one. In order to remedy this, it may be supposed that flat tiles, or stones, would be placed above the posts, having their thicknesses so regulated that the under surface of the architrave, when in a horizontal position, might rest upon each. If this opinion is well founded, one of these tiles may be represented by the abacus of the column in the finished building; and ropes surrounding the tops of the posts, like those in the base, might have been the origin of the echinus, the astragal, and some other of the ornaments, which constitute what is now called the *capital* of the column. The column may, therefore, be considered as formed of three parts or members, *viz.* the base, the body or shaft, and the capital.

It must be owned, however, that bases and capitals are not, universally, the accompaniments of columns; in some edifices, we find columns without bases, in others, we find them without capitals, and there are some columns without either bases or capitals; neither do all capitals of columns resemble ropes or rings, on the contrary we find, in this member, a very great diversity of form, and the talents of artists have been particularly exerted to give it all the beauty of which it is susceptible.

Some columns have their upper extremities adorned with spiral curves, or volutes, projecting beyond the surface of the shaft, and the opinions concerning the origin of these ornaments have been various. Vitruvius asserts that they are imitations of the curls of hair about a woman's head; but later inquirers think they were derived from the curling leaves of plants, or from the horns of animals slain in sacrifice; with which a capricious taste might, on festival days, have decorated the columns of a Temple. It is difficult to say which of these ideas is the most just, and, perhaps, none of them deserve much consideration.

In other columns we find the capitals consist of two or more rows of leaves surrounding the shaft, at its upper extremity, so as to resemble very much the foliage of a plant growing round the side of a cylindrical or bell-shaped vessel. And, according to Vitruvius, it was from the casual observation of such an object, near Corinth, that the idea was first taken. This account of the origin of that particular species of capital has, however, been much controverted; and it is alleged that the representation of foliage, similarly disposed, adorned the tops of Egyptian columns before the time at which the Grecian capital is said to have been invented. However this may be, there is certainly nothing improbable in the supposition that this kind of capital, as well as that last mentioned, was derived from some such appearances.

Lastly, we find that the summits of columns are, sometimes, sculptured to represent the head of a man or woman, or the figures of animals; and we, therefore, conclude that no general type has been followed in designing this member; and that artists, in different circumstances, have chosen such forms as their tastes indicated, in order to obtain a pleasing effect.

The shaft

The shaft of the column is frequently furrowed longitudinally in channels, and various opinions have been started respecting the origin of this practice. If we listen to Vitruvius, he informs us that they were made to represent the folds of a woman's dress; and by some persons they have been supposed to represent the natural inequalities which are found in the bodies of certain trees. But it is conceivable that the stone column might be cut longitudinally in a number of plane faces preparatory to giving it the curved form, and it might easily happen, that some artist, in search of novelty, would chisel out the spaces between the angular ridges, perhaps to increase the effect of his work by the play of light and shade it would produce; and, hence, the channels may have originated. This opinion is rendered more probable by the fact that pillars of a prismatic form are found in some of the Architectural edifices of Egypt and India.

Another opinion has been started by Mr. Mitford (*Principles of Design in Architecture*, let. 7.) which, from its singularity, must not be omitted. He supposes the channellings to have been purposely made to serve as rests for the spears of the warriors, who might deposit them there previous to their entrance into the building; and he founds his opinion upon a passage in the Ist Book of the *Odyssey*, where it is said that Minerva placed her spear by the tall column within the spear-holder, in which were many others. This spear-holder he supposes to mean, one of the channels of the column; and he observes that, in the columns of one of the Temples in Ionia, (that of Minerva Polias at Priene,) the upper surface of one of the mouldings of the base has a horizontal groove surrounding the column, which seems intended to serve as a footing to receive the spears. It is urged, however, in opposition to this theory by Lord Aberdeen, (*Principles of Beauty in Grecian Architecture*, p. 114.) that the place where the spears were deposited was a large receptacle, expressly formed for the purpose, in or near the column, or in the wall of the building, where they might be more conveniently deposited than round the columns; in which situation, his lordship thinks, they must cause an impediment to the passage, and be liable to fall down. Without, however, assenting to the opinion that the channels of columns were originally made for this purpose, we may observe that it would be easy to secure the spears in their places, and prevent any impediment to the communication, by having fillets or cords to surround the column at top and bottom; and by placing the spears in an upright position in the interval of the cord and the concave surfaces of the channels. It may be added that horizontal grooves, similar to those in the bases of the columns of the Temple at Priene, are found in the bases of columns existing in some of the Gothic Cathedrals of Europe; the latter grooves certainly could not have been intended as rests for spears, and they may have been cut, both in these and in the Asiatic columns, merely for ornament. See Wild, *Lincoln Cathedral*, plate xiii.

The trunks of trees are not of equal thickness throughout their length, and this circumstance has been copied in the columns of buildings; which artists have, almost at all times, made to diminish in diameter toward the top, though they are far from being agreed, either upon the precise quantity of the diminution, or upon the form which should be assumed by a section of the column, taken in the direction of its axis.

Origin o
pilasters

In concluding the account of the origin of columns, it may be proper to observe that, occasionally, artists have employed some in the form of square prisms or frusta of Pyramids, to which the name of pilasters is given; and if it is necessary to look for the primitive type of this member also, it may easily be conceived to exist in such posts as were made by cutting the trunks of trees into one or other of those forms.

Origin o
triglyph
and gutt
the enta
blature.

Lastly, the essential ornaments of the members in the entablature of an edifice may have been derived from natural circumstances, which could not fail to afford subjects for imitation. The rain which fell upon the sloping roof would descend from its projecting extremity, would flow across the entablature, and along the columns, and would appear in drops on the under surfaces of the projecting members. This has been supposed to be represented by what are called the *guttæ*, or drops, suspended below the mutules, by the channels cut, as if for the passage of water, in the extremities of the beams which lie across the architrave, and by the guttæ which are formed below the triglyphs. It is not impossible, also, that the channellings of the columns might have been made to represent the courses of rain-water down the shaft. On the other hand, some persons consider the guttæ in the Grecian buildings as imitations of the heads of nails, which may have been driven to attach the members in which they are found to the parts of the edifice above them.

Forms
probabl
uses of
mouldi

The ornamental members about the columns and entablature of a building, which are called by the general name of *mouldings*, project beyond the surface to which they are applied, and their exterior surfaces are either curved or plane, but their particular forms and combinations have been made to depend on our perceptions of beauty, and, perhaps, on the fitness of the members for the purposes to which they are subservient. In plate ii. may be seen the forms of the different mouldings which are employed in both the Greek and Roman Architecture, either to surround the columns, or to extend along the entablature.

We have said that the principal mouldings about the columns, *viz.* the torus, astragal, and echinus, were, probably, derived from the means employed to strengthen and secure the shafts. The same reason, however, cannot be given for all the mouldings which occur either in the columns or in the entablature of the building; and, in the absence of all positive information on this subject, we are reduced to form the best conjectures which the doubtful light of ancient practice will afford. It is probable, then, that it would occur to the first builders of permanent stone edifices, that some small projecting member should mark the separation between any two of the principal parts, as between the architrave and frize; and, for this purpose, a simple *fillet* or *listel*, whose section is a square or rectangle, would serve. But, subsequently, the too frequent repetition of square mouldings, in one and the same edifice or Order, appearing disagreeable, men would naturally be led to vary the surfaces of such mouldings by giving a simple or compound curvature to their sections. Hence would arise the *torus*, *astragal*, *echinus*, *cavetto*, the two kinds of *cymatia*, and that which has been called the *bird's-beak* moulding. These mouldings being introduced, the next step taken to increase the embellishments of the Order, would be, to combine two or more convex mouldings together; and this would require the intervention of a simple fillet or a concave curved moulding, in order to prevent confusion. Such is, no doubt, the origin of the *scotia*, which is generally placed between two tori, or astragals; and, in this way, the system of mouldings constituting the base of a column is formed.

In many ancient examples, (though the practice was not universal,) we find the echinus and the cima reversa employed where a weight is to be sustained, no doubt because their form renders them fit for that purpose. The torus and astragal are well adapted for strengthening the shafts of columns, for which purpose they are used in the bases and capitals. The cavetto and the cima recta were chiefly employed to form a finish at the summit of an edifice, perhaps because their upper extremity, terminating in a thin edge, would render them improper for the purposes of support; while the same members are of importance in throwing off the rain-water, which would flow down the face of the building if it were not for the concave form of their under-surfaces. The bird's-beak moulding is that which most frequently occurs in the Greek edifices; its form is such as to permit it to be used either as a support or as a crowning member, and, accordingly, we find it employed in both circumstances, though most commonly for the former.

All the mouldings above-mentioned afford a field for the chisel of the sculptor, and the last step in the embellishment of an edifice would be, to give them the highest possible degree of ornament. The subjects chosen for this purpose are, sometimes, the figures of animals, but, generally, the leaves of plants, of which Nature presents an inexhaustible variety of beautiful specimens. The meandering ornaments and scrolls so frequently exhibited on ancient edifices are supposed to have been derived from imitations of the ruffled surface of water.

The hypothesis of Vitruvius concerning the primitive model of an edifice, and the opinion that this model was first copied in Greece, were, perhaps, universally acquiesced in till the remains of the Architectural works of the Egyptians became known in Europe. Since that time many artists, being struck with the enormous quantity of masonry employed in the walls of the Temples of Egypt, and with their ponderous roofs, supported by numerous short and massive columns, arranged in close order, have inclined to an opinion that the primitive types of those buildings were the rocks in which the first inhabitants of that Country formed their dwellings or tombs, by excavation; while, from an opinion of the superior antiquity of some of the Egyptian edifices, and from certain resemblances in the ornaments of these edifices to those of the Temples of Greece, they have concluded that the Grecian style of building is but a derivation from the Egyptian, and has no claim to originality.

Probability that the prototype of the Egyptian buildings is a hut.

There is nothing improbable in the opinion that different Tribes of men should have adopted different modes of construction for their original dwellings; and, therefore, we are far from thinking that a timber-house, of the kind before mentioned, was the origin of all the different styles of Architecture which have prevailed in the World. But, with respect to that of Egypt, the huts of the present inhabitants of that Country, which are composed of mud and reeds, built in the form of frusta of Pyramids, and which, probably, resemble those of their remotest ancestors, present, also, so great a similarity of form to the vast masses of masonry placed at the entrances to their ancient Temples, that hardly a doubt can remain concerning the original model from whence the forms of those masses have been derived. It may, perhaps, also be unnecessary to have recourse to a caverned rock for the model of the Egyptian columnar edifices, since a building which, in a burning climate, would be required only to afford shelter from the sun, and a free circulation of air, must, necessarily, consist of a number of pillars supporting a roof. Even some of the tombs that have been excavated in the rocks afford indications of a style drawn from the construction of a building raised from the ground. Above the columns which support the roof is an abacus, sometimes surmounting a capital ornamented with leaves sculptured in the stone; over the abaci is a horizontal band of stone, plain or ornamented, similar to an architrave; and, over all, in front is a projecting cornice, whose inferior surface is, sometimes, sculptured in imitation of reeds, as if disposed there horizontally for the support of the materials forming a roof.

Uncertainty of the opinion that the Grecian style is derived from the Egyptian.

The resemblances said to exist between the Egyptian and Grecian buildings, if we leave out those parts which must, necessarily, be common to all edifices, are found in the capitals of some of the columns employed in both Countries, and in a sort of frize on the faces of some of the Temples in Egypt, on which frize are sculptured, at intervals, in vertical planes, clusters of three reeds constituting an ornament which has been likened to the triglyphs in the entablatures of the buildings of Greece, and from which M. de Pau supposes the latter to have been derived. But these can hardly be considered as affording sufficient ground for establishing a dependence of one style on another; since, without any inter-communication, both people might have invented ornaments which resemble each other so faintly. And the impossibility of fixing the dates of any of the Egyptian buildings, puts it out of our power to ascertain whether those buildings in which the resemblances occur, were, or were not erected before the Greeks acquired an influence in the affairs of Egypt; after this had taken place, it is as likely that the Egyptians copied some of their ornaments from the Greeks, as that the latter should have copied from them.

Possibility of dispensing with an original model.

We have said enough, perhaps, to show that the Vitruvian hypothesis is deserving of some consideration, since it may be made the basis of an elegant system, an adherence to which might operate as a guard against any considerable deviation from propriety and good taste in the execution of a complex edifice. But it must not be understood that this hypothesis alone is capable of guiding an artist in his constructions, or of restraining the excesses of a capricious fancy; since the nature of the building to be raised, and our perceptions of beauty may be, together, sufficient to obtain these ends. In forming a portico, for example, we have to support a roof by means which may leave one or more of the sides open to the air. The roof must, therefore, be borne on columns, and between the breadth and height of these, certain proportions must subsist, which experience would soon determine for the best. The entablature might be, originally, one plain mass of stone, but it would be subsequently found more pleasing to divide its exterior surface, horizontally, into two or more parts by projecting mouldings, and to ornament the faciæ in various ways, which would produce an agreeable play of light and shadow; and lastly, the capitals of the columns may have been, originally, simple blocks broader than the shafts in order to increase the points of support under the entablature; and these would soon, by the taste of artists, be brought to the graceful forms they have since exhibited.

Supposed origin of the Chinese Architecture.

One nation only, *viz.* the Chinese, is considered as having adopted a mode of building derived from the forms of the tents in use among a pastoral people. But from the lightness of construction, which is the characteristic of that style, the buildings are not of long duration; therefore, the specimens which that Country affords are, all, of comparatively recent date; and it will be better to defer the consideration of them till we come to the period in which that style was made known to the people of Europe.

CHAPTER III.

The Invention of Architecture among the Greeks

Seats of the first Empires.

Almost as soon after the Noachian Deluge as Society could be formed, we read that Nimrod and Ashur built the cities of Babylon and Nineveh, and founded Empires in the regions of Chaldea and Assyria, along the courses of the Euphrates and Tigris. From these territories proceeded colonies to Africa, Europe, and, probably, to the more Eastern parts of Asia, all which places, in process of time, became the seats of powerful Monarchies, and the sea-coast of Syria must have been soon covered with populous cities, which, in the time of Moses and Joshua, that is, within 500 years from the Flood, were of so much importance as to be surrounded by walls, which, from their loftiness, are described as reaching to heaven. In the plains of Assyria, stone being sparingly distributed by the hand of Nature, the material employed in building was chiefly brick; and the perishable quality of this material, together with the frequent wars which desolated a territory situated between the powerful Monarchies of Egypt and Persia, will account for the entire disappearance of all the earlier Architectural works raised in that part of the World.

Situations of Babylon, Nineveh, and Ecbatana.

The city of Babylon was situated in the Delta formed by the Euphrates and the Tigris, about the thirty-second degree of North latitude. It was brought to the highest degree of its perfection by Nebuchadnezzar about six hundred years before the Christian Era; but its splendour must have been of short duration, as it was taken by Cyrus about sixty years after the death of that Monarch, and, from that time, it gradually declined. What its ancient condition was we have no means of knowing, except by the description of Herodotus. He says (*Clio*, sect. 181.) it was situated on each side of the Euphrates, and the whole formed a square, each side of which was fifteen miles long; it was divided by twenty-five parallel streets, running from North to South, and by as many, also parallel to each other, from East to West. The walls were 387 feet high, and 87 feet thick, all built of brick, and there was a quay of the same material along each side of the river, which was crossed by a bridge, formed by laying great horizontal stones over the tops of piers, built in the bed of the river. In the centre of each division was a circular space surrounded by a wall; in one of these stood the Royal Palace, whose walls were adorned with sculpture, and the Temple of Jupiter Belus occupied the other.

The ruins of this celebrated city have been lately visited by several European travellers; according to Mr. Rich, they extend on both sides of the Euphrates between Mohawil and Hellah, 48 miles from Bagdad, and consist of immense masses of brickwork, buried under earth which has been accumulating over them for Ages. The bricks obtained from these heaps bear inscriptions which have been the subjects of many learned discussions; and, recently, a large statue of a lion has been discovered among the ruins; but, as yet, it is impossible to trace the line of the ancient walls, or to ascertain, with certainty, the site of the Tower of Belus.

The city of Nineveh was of equal antiquity and, probably, of equal magnitude with the city of Babylon; it is, now, entirely destroyed; but it is supposed to have been situated on the Tigris, in about the thirty-sixth degree of North latitude, near the spot on which the city of Mosul now stands.

Ecbatana, the Capital of the Median Kings, was also a city of great magnitude, and surrounded by seven walls, rising gradually each above the next towards the interior; this, also, has been destroyed; but it is supposed to have been situated in the North of Persia, near the present town of Hamadan, in about the thirty-fourth degree of North latitude.

The Egyptian Thebes, situated near the Southern extremity of that Empire, is the most ancient city of whose buildings any remains subsist at the present time. The period of its foundation ascends, probably, to the same antiquity as that of Babylon and Nineveh. It was the first seat of the Egyptian Government, but, at an early period of the History of the World, that seat was transferred to Memphis, near the Northern extremity of the Empire. From this time its importance declined; but the imperishable nature of the materials, the dryness of the climate, and the immensity of the masses, have preserved the buildings through all the vicissitudes of three thousand years. Memphis, less fortunately situated, by being nearer the line of communication between Asia and Africa, has been more subject to the destructive caprices of Man, and has disappeared from the face of the Earth, so that its situation is entirely unknown. The Pyramids, however, which were in its vicinity, still exist.

About fifteen hundred years before the Christian Era, colonies from Syria extended themselves to the Countries bordering the Archipelago, and brought the Science of Legislation, and the Art of building to those uncivilized lands. From this time we may, perhaps, date the origin of the principal cities of Greece, though the existing remains of their purest Architecture belonged to edifices erected a thousand years later. The cities of Asia Minor, Sicily, and Italy were probably founded between the years 1000 and 700 before Christ; and, both in these and in the cities of Greece, are displayed the first monuments of a school of Architecture which, subsequently, prevailed throughout the civilized World, till the Arts and Sciences fell with the Roman Empire, and which, after a long sleep, revived in the XVth century; since that time it has extended itself over Europe, and, till very lately, it formed, exclusively, the style of the artists of this quarter of the World.

In Syria, the city of Jerusalem is yet known by its ancient name; its prosperity was at the highest point in the days of Solomon, about nine hundred and ninety years before Christ; at which time it contained a splendid Temple dedicated to the true God. The cities of Balbec and Palmyra, in the same part of Asia, must have been considerable at a very early period; but the ruins at present existing on their site, and those more recently discovered near the Jordan, belong to the time of the Roman power in that region.

Persepolis, situated further Eastward, still presents some ruins, the date of which is referred to the time of Cambyses, though the city itself is probably much more ancient.

In India, two cities of great antiquity once existed, viz. Canouge and Palibothra,* (if these names were not both given to the same place.) The former was situated on the Ganges, according both to Strabo and Arrian; who add, also, that its form was quadrangular, its length 80 stadia, perhaps about 8 miles, and its breadth 15 stadia, or 1½ mile. According to the Poem *Mahabbarit*, it was founded about one thousand years before Christ, but we know nothing of its buildings.

Since the Architecture of Egypt is commonly considered as more ancient than that of Greece, it would seem that we ought to proceed, immediately, to exhibit the character of the former in the remains of the ancient Temples and Tombs of that Country. We prefer, however, to begin with the Architecture of Greece, because, in the latter Country, from a few simple and cognizable principles, the Art grew up into a perfect system, which has stood the test of more than twenty-five centuries; and, with some exceptions and modifications, constitutes the Architecture of Europe at the present day. With this, as a standard, we are accustomed to compare both the Egyptian and Roman styles of Architecture; and without an accurate knowledge of the dispositions and proportions of the different members which compose the Grecian system, the others cannot be conveniently described, nor easily understood.

Cadmus probably first induced the people of Greece to build their habitations near each other, and to surround them by walls for the purposes of defence; and thus their earliest cities were formed. Near Argos are still to be seen the remains of the walls of Tirynthus, which, probably, formed a military post or citadel for the protection of that part of the Country. The construction of these walls must be referred to a very early date, though the precise time is unknown; according, however, to the testimony of Strabo and Pausanias, they were erected at a period which must have preceded the Trojan war, and by a people who had emigrated from Lycia. In common with several other works of a similar nature yet remaining in Greece, they were by the people considered as a work of the Cyclopes; a Tribe which is supposed to have arrived there from Thrace, and to have founded colonies in the Country. The stones of which the walls are composed are rudely shaped and placed together; and passing through the wall there is a gallery formed of stones laid in horizontal courses, but projecting over each other, so that the sides approach together at the top, and a vertical section of the gallery is of a triangular form.

The Treasury of Atreus at Mycenæ.

In those times the lawless character of the people, or the danger of being surprised by invading enemies, rendered it necessary to construct strong places for the purpose of securing the wealth of the Prince or of the State. The earliest of these buildings seems to have been erected at Orchomenos by Minyas, a King in Bœotia; and it is described by Pausanias (*Bœotica*, c. 38.) as one of the most wonderful productions of Grecian Art. But the most interesting to us, because it remains in a tolerable state of preservation, is the subterranean chamber at Mycenæ, which is called the Treasury of Atreus. This also is mentioned by Pausanias. (*Argolica*, c. 17.) The entrance to the chamber is by a passage 20 feet 6 inches wide, between two parallel walls, the remains of which are about 50 feet long; this passage is open to the sky; and, at its extremity, is the entrance, which forms a gallery 18 feet long and 8 feet wide, covered by flat stones; but having above them a triangular arch, if it may be so called, consisting of horizontal courses of stones, like those in the gallery at Tirynthus before described, and probably intended to lessen the pressure of the horizontal ceiling of the gallery. At the extremity of this gallery is the chamber, which is of a circular form, and 48 feet 6 inches diameter; the walls are formed of circular courses of stones laid horizontally on each other; each course projecting towards the interior, beyond the course below, till they meet in an apex over the centre; thus producing a resemblance to the inside of a dome. The height of the chamber is 45 feet; and a section taken vertically through the centre forms nearly a parabola, or rather two segments of circles rising perpendicularly from the pavement and meeting nearly in a point at the top. The interior projections of the stones have been cut to form a smooth surface, but there is a little irregularity in one part, probably caused by some accidental displacement of the materials. The whole of the internal surface appears to have been lined with plates of bronze.

On one side of the circular apartment is a square chamber 27 feet long and 23 feet wide; and between the chambers is a communication through a narrow passage formed in a manner similar to the gallery before mentioned. There are several subterranean chambers, similar to this, near the same place, and the Treasury at Orchomenos, mentioned above, appears from Pausanias to have been of similar form; many similar buildings also exist in Egypt, Sicily, and Italy.

About the chamber at Mycenæ are scattered many heterogeneous enrichments which appear to have belonged to the building; and from these Mr. Donaldson has given, in the *Supplement* to Stuart's *Antiquities of Athens*, a design for the restoration of the façade at the entrance of the building. The exterior of the wall, which is shown in pl. i. fig. 3., appears to have been faced with red, white, and green marbles, embellished with zig zags and scrolls; a species of ornament which is frequent on the fragments of ceramic vases found

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* See Col. Francklin's learned *Inquiry concerning the Site* of this City.

about the same place; and the holes for the cramps by which the marbles were attached to the wall are still visible. On each side of the door-way, he supposes a column to have been placed, the form and ornaments of which he has made out from a base and part of a shaft discovered among the ruins. See pl. i. fig. 4.

Walls of Mycenæ.

On that side of Mycenæ which is opposite the Treasury of Atreus, remain what appear to be parts of the ancient walls of the city, and which, according to popular tradition, formed part of the Palace of Agamemnon. The entrance is by an aperture similar to that of the Treasury of Atreus, being formed by two vertical jambs and a horizontal lintel, rudely executed. Above this is a piece of sculpture representing two lions, each about ten feet high; one on each side of a short column, with their fore feet placed on a sort of pedestal. From these figures, the aperture has obtained the name of the Gate of the Lions. This gateway is mentioned by Pausanias, (*Argolica*, c. 17.) who also states that in his day it was reported to be a work of the Cyclopes.

The supposed origin of Temples.

The notices we have of the earliest Temples in Greece or Asia are so few and unsatisfactory that what can be said of them may be delivered in a few words. The Sacerdotal office, which at first was possessed by the father of each family, became, in some Countries, by the establishment of a Monarchical Government, vested in the Prince; and where this happened, there is reason to believe that some division of the Regal Palace was set apart for the offices of Religion. But when, subsequently, a regular Order of Priests was formed, it would no doubt be found convenient to have places expressly appointed for performing the sacrifices; and therefore Temples would be erected.

Before the time of Homer there were few Temples in Greece. Those he mentions are of Minerva at Athens, Apollo at Delphi, and Neptune at Ægæ. He often represents sacrifices performed on altars in the open air; and it is plain from the terms which he employs that the Fanes of Minerva and of Apollo were roofless. That Temples existed on the Asiatic coast before his time is certain, for Hecuba is described by him as leading a procession of matrons to the Temple of Minerva in the city of Troy, in order to propitiate the Goddess.

The Palaces of Priam

From the description, in the *Iliad*, of King Priam's Palace, we may obtain some idea of the public buildings in that part of Asia about Homer's time. This edifice is stated by him to have been built of stone, and to have consisted of a court surrounded by apartments; of which there were fifty on one side for his sons, and twelve opposite them for his daughters and their husbands; besides these, there were the apartments occupied by the Monarch himself.

and Ulysses.

From what we can collect, in the *Odyssey*, of the Palace of Ulysses, its plan does not seem to have been very different from that of King Priam's Palace. It appears to have consisted of an αὐλὴ, which, from the derivation of the word, may be concluded to be a court without a roof; this was surrounded by the apartments, some of which must have been formed with a lower and an upper story; for Penelope occupied the upper rooms in one part of the house, and the armoury was up stairs in another part. But it is probable that in some places the house might have consisted only of a ground-floor; for Minerva, in the shape of a bird, placed herself upon a rafter or beam, and beheld from it the destruction of the suitors; therefore, there could have been no ceiling in this part between the pavement of the room, which was on the ground-floor, and the roof; the latter was, probably, formed of rafters resting on the walls, and meeting in a ridge or point at top. Columns are mentioned by Homer, as having a place in this building; but it is remarked by Lord Aberdeen, that he makes no allusion to their beauty; it is therefore probable that they were nothing more than wooden posts; and as a cable was stretched between them and the wall, for the purpose of executing the guilty attendants of Penelope, (*Odyssey*, book xxii.) we may infer that they surrounded the central part of the aula, or court, at a distance from the walls. Mr. Gwilt, in an interesting Essay prefixed to his edition of Sir William Chambers's *Architecture*, infers, from the epithet sonorous, applied by Homer to the 'Αιθούσα, or passage between the columns and the walls, that it was covered by a roof.

It has been observed that the *Odyssey* was composed at a later period than the *Iliad;* and therefore the description just given may not apply correctly to the style of building employed at the time of the Trojan war. It is not, however, likely that the interval between the times of composing the two Works was considerable, and it is evident that the character of the building is such as prevailed among the Greeks at a very early period, which is all that it is necessary to show.

In the buildings consisting of open courts surrounded by apartments, we see also the first examples of a ground-plan, which has been ever since practised very generally for the dwellings both of Princes and private individuals of rank, in the whole extent of Europe and Asia; from Spain to China.

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The roofs of houses in the Homeric times were sometimes formed by two or more inclined planes, meeting in a ridge or point above; as we have seen reason to believe from the description of the Palace of Ulysses, and as may be shown from a passage in the *Iliad*, in which two men wrestling are compared to two beams in the roof of a house. But it is also evident that in some cases the roofs were flat; of which the Palace of Circe affords an example, since Elpenor, one of the companions of Ulysses, was killed by falling from it.

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At a time more ancient than that of Homer's heroes, we learn that the houses in the East were built with flat roofs; for, in the Book of *Deuteronomy*, the people of Israel are commanded to surround the roofs of their houses by a rail or parapet, to prevent any person from falling off. And since, in all Ages, in that part of the World, there has been little variety of fashion in houses, furniture, and dress, and the manners and customs of the people are nearly the same now as in the time of Moses, we may safely conclude that manner of building was then, as it is at present, general both in Syria and Egypt. To these terraces there was an ascent by steps on the outside of the house, and the fineness of the climate permitted the inhabitants to use them for the purpose of repose as well as of exercise.

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From the war of Troy till the time of the Ionian migration, a period of about a century and a half, little is known of the state of Architecture in Greece. Vitruvius, indeed, says, (chap. i. book iv.) that a Temple, dedicated to Juno, was erected at Argos during the reign of Dorus, the son of Hellenus, which must have been more than twelve hundred years before Christ: he states that it was built according to the Order, since called the Doric, and he asserts that the same Order was, subsequently, used in the other cities of Greece. He admits that the proportions of the Order, meaning, no doubt, the relations between the dimensions of the different parts of the columns and entablatures, were not then reduced to any system; we must, therefore, suppose that the Greeks, at that time, had no fixed principles to guide them in the construction of their buildings.

Whatever progress the Greeks might have made in civilization and Art during that period, it seems certain that it was arrested by the return of the Heraclidæ to Peloponnesus. This people, driving from their dwellings the inhabitants of a considerable part of the Country, and maintaining a sanguinary warfare with those who remained, so much unsettled the minds of men that no leisure could be found for cultivating the Arts of Peace.

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While the political affairs of Greece were in this perturbed state, a Body of adventurers from it, under the command of Ion, the son of Xuthus, colonized that part of Asia which was before inhabited by the Carians and Leleges. Then it was, as Vitruvius asserts, that the Temple of Apollo Panionios was erected by the colonists in a manner resembling the Temples of Greece. These persons, being ignorant of the proportions which the columns should have, in order to support the roof, conceived the idea of making them correspond to the dimensions of the figure of a man; the height of which is about six times its breadth. They, accordingly, made the diameter of the column, at its foot, equal to one-sixth of its whole length; and the system, or Order, which received those proportions, they are said to have called the Doric, because it had been first used in the cities of the Dorians; by which name, at that time, probably, all the Greeks who lived to the North of the Gulf of Corinth were called; and, perhaps, also, to distinguish it from another system or Order which, Vitruvius says, was invented or used by Ion himself, and, on that account, called the Ionic Order.

In establishing the proportions of this latter Order, Vitruvius asserts, that the inventor copied the dimensions of the figure of a matron, which is, in general, more slender than that of a man; and he gave to the diameter of this kind of column, at its base, one-eighth of its whole length, by which it assumes a more graceful appearance than the other. Vitruvius goes on to state that the ornamental parts about the Ionic column were intended for resemblances to different parts of the dress of a woman. Thus the mouldings of the base were intended to represent the shoe; the volutes of the capital, to represent tresses of hair curling on the right and left of the head; and the channels of the shafts, to represent the folds of the garments.

If we may give credit again to Vitruvius, a third Order was subsequently invented, by a sculptor named Callimachus, who is said to have lived about the end of the Peloponnesian war. This Order was, afterward, called the Corinthian, and it has been supposed that the artist, wishing to give to his columns more delicacy than was possessed by those of the Ionic Order, adopted the proportions observed in the figures of young women. Vitruvius, however, does not determine what part of the whole length of the column is equal to the diameter, and, in all probability, the practice of different artists was very various. The circumstance from which the capital of this Order originated, has already been alluded to, and the following tale concerning it is stated by Vitruvius from report. He says that a young woman of Corinth, being just marriageable, was seized with a disorder, and died; after her interment, her nurse collected in a basket the toys which pleased her when alive, placed the whole over her grave, and covered them with a tile. The basket happened to be placed over the root of an acanthus, which, afterwards, grew up round its exterior, and curled under the angles of the tile. This being observed by Callimachus, he took from it the idea of the capital of a column; and, whatever we may think of this story, there is certainly no improbability in the supposition that the ornament in question was derived from the appearance of some plant encircling a vase.

The Greeks invented an Architecture founded on proportions.

When we contemplate the account which Vitruvius has given of the origin of these Orders, we cannot avoid recognising, in some parts of it, the liveliness of imagination which has always characterised the Greeks; and, while we suffer ourselves to be amused by the circumstances he relates, we are cautious of considering them as entitled to implicit confidence.

It will, however, be hardly fair to refuse our assent entirely to the general facts, whatever we may think of the particular circumstances; for, among a people so exquisitely refined as the ancient Greeks, it is highly probable that an imitation of natural objects would be adopted, both for the purposes of ornament, and to establish a system of proportions, by which the magnitudes and dispositions of the members of their edifices might be determined. This imitation was at first, no doubt, rude, but by the liberty which that people took of altering the proportions according to the dictates of an improving taste, their Architecture finally acquired that degree of perfection in which it has been transmitted to the present times.

The Egyptian Architecture was not reduced to a system.

The architectural works of the Egyptians, as well as those of the Greeks, bear the marks of a very remote period; and, if we consider only the probable ages of some particular edifices, the claim of even superior antiquity may, by some, be decided in favour of the former people; but, if we consider Architecture as an Art founded on a system of proportions, we think there can be little doubt that the Greeks are really the inventors of that Art; since, as is observed by a French writer, among the other people, there is not found any expression of the characters of edifices by those variations in the proportions which constitute the different Orders of Architecture. The Egyptians employed columns in their buildings at a period, at least, as early as those of the oldest recorded in the descriptions of Greece; and, long before the time of the supposed invention of the Corinthian capital, there existed columns in Egypt, the heads of which were ornamented with sculptured leaves of the palm or lotus. But in the Grecian edifices, the principal ornaments are always, respectively, made to accompany one particular Order, which differs in the proportions of its parts from another Order; while, of the Egyptian works, there is nothing, in the proportions, by which we may distinguish either the columns or entablature of a building in which certain ornaments exist, from those in which they do not so.

Opinion that the Greeks might have modified the Egyptian Architecture

The intercourse between Egypt and Greece became general about the year 679 before Christ, when the 1st Psammeticus entered into an alliance with the Greeks, in order to be supported by them on his throne. And it is an opinion, entertained by some persons, that the existing examples of Egypt were executed, or restored, by Grecian artists at the time that this intercourse subsisted between the two Countries. We are far, however, from thinking that this opinion is well founded, because, on account of the extreme veneration entertained by the Egyptians for every object connected with their Religion, they never suffered any but their Priests, or persons subordinate to them, to perform any of the services required about their sacred edifices; it is not likely, therefore, that foreigners would be allowed to change the style of their Architecture.

CHAPTER IV.

Description of the Grecian Doric Temples.

Temples are, in general, the most ancient buildings remaining.

In Greece, as well as in Egypt, nearly all the most ancient specimens of regular Architecture, yet remaining, are the Temples which were consecrated to the Gods. These, being constructed with great solidity, and not subject to the mutations which affect buildings intended for domestic purposes, might be expected to survive all such edifices; and, as they possess, at the same time, a simplicity of character which causes their form to approach very near to what is supposed to have been that of the primitive model, it will be proper, in describing the Grecian buildings, to begin with the Temples. This we purpose to do after having stated the different denominations which, according to Vitruvius, were assigned to them, on account of the disposition and number of the columns employed.

General plan of the ancient Temples.

The Greek Temples were, almost universally, rectangular, only one or two examples remaining of a circular or polygonal form, though, no doubt, many such existed formerly. These, however, were small, in some cases the building consisted merely of a row of columns, disposed on the circumference of a circle, and covered by a roof; in others, a space was enclosed by a cylindrical wall, covered by a roof, which projected beyond the wall, and was supported by a circular range of columns. These Temples were said to be *monopteral.*

The plan of the generality of the rectangular Temples in Greece and her colonies was a simple parallelogram, a form which also prevailed in the Temples of Egypt. In some of the smaller Temples a row of columns was placed in front; but, in most cases, there was a row both in front and rear. And the superior Temples were, generally, surrounded by one, or even two ranges of columns. The Temple was divided into two or more parts; in the front, and, sometimes, in the rear face was formed a porch; beyond this, or between the two, was the *naos*, or body of the building, into which the worshippers were admitted; and, at one extremity, separated from it by a wall, was, sometimes, an apartment called *opisthodomus*, to contain the treasures of the Temple or of the State, and into which the Priest, or the chief Magistrates only, were allowed to enter. The porch in front was called *pronaos*, and that in the rear, *posticos*. The interior of the naos was without ornament, and, generally, received its light from the door only, or, perhaps, from openings formed in the roof; though, in some cases, windows were formed in the walls.

The roofs of the rectangular Temples were formed in two inclined planes, extending from front to rear, meeting in a ridge over the middle, and forming a triangular pediment at each extremity. Above the walls, at the angles of the building, are generally placed *acroteria*, or pedestals, which rise through the roof to about the level of the centre of the tympanum. On the upper surface of each of these pedestals a square place is sunk, probably for the reception of some figure which might be intended to ornament the roof.

The simplest form of the rectangular Temple was that in which the two side walls were carried out from the naos, to form the porch before mentioned, at one or both extremities of the building. These projecting walls were terminated on the front, or on both faces of the building, by pilasters, which, thus situated, were called *antæ;* and, hence, this kind of Temple was said to be *in antis.* Between the pilasters in front were placed two or more columns which, with the pilasters, supported the entablature.

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When columns were placed at one extremity of the building, in advance of the line joining the antæ, the Temple was said to be *prostyle;* the entablature was placed over the front columns, and returned on the right and left as far as the antæ, or, perhaps, quite along the sides of the building. If columns were placed, in a similar way, at both extremities of the building, it was said to be *amphiprostyle.*

A Temple having columns entirely surrounding the walls was called *peripteral;* in which kind of Temple a space equal to an intercolumniation, that is, to the distance between two columns, is supposed by Vitruvius to be left between the columns and each of the side walls of the naos; to which spaces the Greeks gave the name of *pteromata.* When the exterior of a Temple was not surrounded by a peristyle or colonnade, the Temple was said to be *apteral.*

A Temple was of the kind called *dipteral*, when it had two ranges of columns resting on the pavement, and entirely surrounding the naos. When there were two rows of columns in front and rear, and only a single row on each flank, the temple was said to be *pseudodipteral.* In this case, a space equal to the extent of two intercolumniations existed between each of the side walls and the columns.

A Temple was called *Hypæthral* when it had a row of columns in the interior at some distance from each of the four walls. The space between the walls and the columns may, in some cases, have been covered by a roof, but the central space enclosed by the columns had none. Hypæthral Temples being those of the greatest magnitude, had, generally, a double range of columns surrounding the naos on the exterior; and they are supposed by some to have been mostly, if not always, dedicated to Jupiter; but this is very doubtful.

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Vitruvius, in the IId Chapter of his IIId Book, distinguishes Temples according to the magnitudes of the intervals of the columns; thus a Temple is said to be *pycnostyle* when the interval between the nearest sides of the columns is equal to once and a half the diameter of the column. It is said to be *systyle*, when that interval is equal to two diameters. But he considers both these kinds as inconvenient, because persons entering the Temple arm in arm cannot pass between the columns.

The next kind is called *eustyle*, in which the intervals were equal to two diameters and a quarter, or two and a half, except one interval, *viz.* that in the middle of the front and rear faces, which was a little greater. This kind he considers as uniting beauty, convenience, and strength.

Another kind was called *diastyle*, in which the intercolumniation is equal to three diameters; he considers this as, in general, too wide, since the architrave, if made of stone, was liable to break.

Lastly, the kind called *aræostyle* has the columns placed at considerable, but undetermined intervals from each other; the entablature is supposed to be formed of timber, and, where this disposition is employed, the whole edifice is made low and broad.

It may also be observed, that Temples were distinguished according to the number of columns they had in front; thus we read of *tetrastyle*, *hexastyle*, *octastyle*, and *decastyle* Temples, which denominations were, respectively, applied to them according as they had four, six, eight, or ten columns in front.

We proceed next to give a concise description of some of the principal Temples in Greece and its ancient colonies, and to state their general dimensions, in order to afford data for determining the characters and proportions of the several Orders of Architecture employed in the edifices of those Countries. And, as the existing specimens of the Doric Order are the most ancient, we begin with them. The dimensions are expressed in English feet, decimally divided, for the sake of comparing them together with facility; in the VIIth Chapter is given a general Table, in the same measure, of the dimensions of the columns and entablatures; and in plates iii., iv., and v., are elevations of the same columns, showing the proportions of their several members. In the plates, the lines of numbers marked H, express the heights of the members individually, and those marked P, their projections from the axis of the column. Agreeably to the general practice, the module, or lower diameter of the shaft of each column, is supposed to be divided into sixty equal parts, called minutes, and the integers in the lines of numbers are of that denomination.

Probably, one of the earliest Temples the remains of which are still to be seen is that at Corinth. It is of the Doric Order, and the proportions of the members of its columns seem to show that it must have been erected before Architecture had acquired that perfection which distinguished the Athenian buildings of the time of Pericles. The disposition of the columns which are yet standing have led the authors of the *Antiquities of Athens* to believe that the Temple must have been of the kind called peripteral and hexastyle. Its form seems to have been rectangular, and, measuring on the exterior of all the columns, it must have been about 160 feet long and 109 feet wide. The columns are 23.7 feet high, from the foot of the shaft to the top of the capital, and the diameter, at bottom, is 5.83 feet; consequently, the whole height of the column is equal to 4.06 diameters, which makes the ratio of the diameter to that height greater in this than in any other of the Greek examples. The diminution, or difference of the diameters at the top and bottom of the shaft, is nearly equal to one-quarter of the lower diameter, and the difference of the two semidiameters is $\frac{1}{30}$ of the height of the shaft.

The capital consists of an abacus and echinus with three rectangular fillets surrounding the column under the latter member. A little below the fillets are three channels cut round the column, forming a separation between the main body of the shaft and what is called the *hypotrachelion*, or that part immediately below the capital. The shaft, which consists of but one block of stone, is cut longitudinally by twenty channels or flutes, each of which forms, on the plan, a segment of a circle whose radius is equal to the breadth of the channel. These channels extend from the foot of the column to the fillets under the echinus.

The frize and cornice are entirely gone, but part of the architrave remains; the height of this member of the entablature is 4.722 feet, or about one-fifth of the height of the column, and its face is in a vertical plane, which, if produced downward, would fall a little within the foot of the column. The distance between the centres of the columns is 13.5 feet, and the intercolumniation, or distance between the nearest sides, is 7.67 feet, or nearly 1⅓ diameter.

The Temple at Ægina.

The Temple of Jupiter Panhellenius at Ægina seems to be of equal antiquity, though it is impossible to assign a date to either. It is, however, observed by Lord Aberdeen that, as the State of Ægina fell into obscurity almost immediately after the Persian invasion of Greece, it is unlikely that such a building would have been erected subsequently to that period. The Temple, which was of a rectangular form, of the Doric Order, and peripteral, was 90.5 feet long and 41.5 feet wide, measuring on a line circumscribing all the columns. According to Dr. Chandler, it had six columns at each extremity and twelve on each flank, including the extreme columns, with two columns between the antæ. The Temple itself was divided into three parts, forming a pronaos, naos, and posticos, and is supposed to have been hypæthral, as three columns are yet to be seen which must have belonged to the interior. The height of each of the exterior columns is 15.796 feet, and the diameter, at bottom, is 2.927 feet, so that the whole height of the column is equal to 5.397 times its diameter; the difference of the two diameters is nearly equal to one-quarter of the lower diameter, and the difference of the semidiameters is $\frac{1}{38}$ of the height of the shaft. The architraves and frizes of the entablature remain, but the cornice is wanting; the height of each of the former members is nearly equal to 2.5 feet, or to one-sixth of the height of the column.

When the Greeks colonized Sicily, about 650 years before Christ, they carried with them the principles of their Architecture; and within a period of 250 years, during which time the States they founded enjoyed an independent existence, several Temples of the Doric Order were erected, the ruins of which yet subsist. To this island, therefore, we must look for other specimens of that Order, whose execution may be referred to an early Age.

The great Temple at Selinus.

The ruins of Selinus occupy two hills and the valley between them. On the Eastern hill are the remains of three Temples lying nearly in one direction, *viz.* from North to South; of these the first appears to have been one of the largest of the sacred structures of antiquity, and is, therefore, supposed to have been dedicated to Jupiter Olympius. It was octastyle, with seventeen columns on each flank, pseudodipteral, and probably hypæthral. The plan was rectangular, and the building was raised on a *stereobata*, or basement, the sides of which were formed in three steps surrounding the whole. Its length was 331 feet and breadth 161 feet, measured on the upper step and on a line circumscribing all the exterior columns. The breadth of the body of the Temple within the walls was 67.25 feet, and its length was probably about three times its breadth. The pronaos and posticos were, each, about 65 feet long; the walls of both were terminated by antæ pilasters, between which were two columns; and before the pronaos was a portico having four columns in front, with one between each of the extreme columns and the antæ. Three entrances conducted from the pronaos to the cella which was divided into three parts, longitudinally, by two rows of Doric columns, eleven in each row, at the distance of 20 feet from the walls.

The height of the columns surrounding the Temple is 48.583 feet, including the capital, and the diameter at the bottom of the shaft is 10.625 feet, so that the height of the column is equal to about 4.5 diameters; the difference of the upper and lower diameter is $\frac{1}{3.5}$ of the latter, and the difference of the semidiameters is $\frac{1}{30.28}$ of the length of the shaft; a greater diminution than is found in any other example with which we are acquainted. The flutings on the shaft are shallow, and there is a narrow, longitudinal fillet between them; and a narrow groove is cut round the shaft immediately below the fillets of the echinus. The faces of the architrave and of the metopes in the frize are in a vertical plane, which, if produced, would fall about the middle of the face of the shaft; and the faces of the triglyphs project beyond that of the frize. A plain course of stone lies above the corona, and the entablature is crowned by a pediment the inclining sides of which are also formed of two plain courses of masonry.

The heights of the architrave and frize are, nearly, equal to each other, and that of the cornice is about one-half of each. The height of the whole entablature is 21.76 feet, which is about $\frac{1}{2.23}$ of the height of the column.

The central Temple is 200 feet Southward of the former, and the third is 154 feet Southward of the last; both of them are hexastyle and peripteral, but the former has fourteen columns on each flank, and the latter, fifteen. The pronaos, or vestibule, of the central Temple seems to have been enclosed by bronze gates or doors, as the grooves in which they turned are still visible.

On the Western hill, which is supposed to have been the Acropolis, are the remains of a wall, nearly a mile in circuit, and enclosing a space covered with the ruins of buildings, among which, the remains of three Temples have been made out. All the six Temples are of the Doric Order, built of limestone covered with fine plaster, and several members of their entablatures have been painted. The Architecture and sculpture of these Temples have been beautifully illustrated by Messrs. Angell and Evans in their recent publication on the sculptured metopes in the ruins of Selinus.

The Temple at Ægesta.

At Ægesta, or Segesta, are the remains of a Temple 190 feet long and 76.7 feet wide, measured on the upper step as before. This was hexastyle, amphiprostyle, and peripteral, with fourteen columns on each flank, and two columns between the antæ both of the pronaos and posticos. Each column is 30.096 feet high, and the bottom diameter is 6.6 feet; consequently the height of the column is equal to 4.56 diameters. The shafts of these columns are entirely plain, and a groove is cut round them at the foot, either to produce a dark shadow, or to serve for the reception of bronze ornaments which might be occasionally fixed on. The height of the whole entablature is 14.77 feet, which is $\frac{1}{2.04}$ of the height of the columns; the faces of the architrave and of the metopes in the frize are in a plane, which, if produced, would pass through the middle of the front of the shaft; and the faces of the triglyphs project beyond that of the frize. In the vertical face of each step on the four sides of the stereobata is a row of small blocks of stone, and a horizontal groove is cut along the bottom of the same face.

The Te
of Mine
at Syra

The Temple of Minerva at Syracuse is 182 feet long and 74 feet wide, measured also on the upper step, and has the same characters as the Temple last mentioned; the height of the columns surrounding it is 28.667 feet, including the capital, and the bottom diameter is 6.503 feet.

The columns of this Temple are remarkable for standing on a plinth, which is not the case in any other example of the Grecian Doric Order. The columns of the pronaos are still further remarkable in being thicker than those which surround the building, in having an astragal under the echinus, and a base, consisting of two astragals on a low plinth, with a fillet above; circumstances which have led to an opinion, that though this Temple is, undoubtedly, one of the most ancient in Sicily, these columns must have been set up subsequently to the construction of the rest of the building.

Templ
Agrig

At Agrigentum are the remains of two Temples, nearly similar to each other, and nearly of the same size, of which one is dedicated to Juno Lucina, and the other to Concord. Both are hexastyle, peripteral, and amphiprostyle, with thirteen columns in each flank. The length of the Temple of Juno is 124 feet, and its breadth 57 feet, measuring on the upper step. The height of the columns is 20.833 feet, and their lower diameter is 4.508 feet; the architrave and frize remain, but the cornice is wanting. In the stereobata of this Temple is a doorway leading to a subterranean gallery, communicating with the interior of the edifice.

The Temple of Concord is smaller than the other, its length being 93.75 feet, and breadth 31 feet. An entablature surrounds the walls of the cella, in the frise of which are triglyphs, and the cornice above them is crowned by a cavetto. But the most remarkable circumstance is, that there are no mouldings on the horizontal corona, nor on the sloping sides of the pediment. The height of the columns is 21.51 feet, and the lower diameter 6.42 feet.

At the same place was, formerly, a Temple dedicated to Jupiter, which must have been of vast magnitude; according to Diodorus it was 340 feet long, 60 feet broad, (probably 160 feet,) and 120 feet high. Instead of having pteromata, or walks, round the exterior of the body of the Temple, the walls seem to have been built between the exterior columns, so that half of each column projected beyond the face of the wall. The semicircumference of each column was equal to 20 feet, and the flutings were so large that a man could stand in one.

The T
at P

At Pæstum, on the Gulf of Salerno, in Italy, are the remains of two Temples of the Doric order, which, though, in their general features, resembling the style of the Sicilian Temples, yet, in some points, appear to approach the forms which characterised the later examples of the Grecian school. The author of the *Antiquities of Magna Græcia* even supposes that they may be of an Age subsequent to the Roman conquest of the Country; the Roman style, he observes, seeming to predominate over the borrowed features of the Grecian. A certain sentiment, however, which is perceptible in the designs, and the quality of the workmanship, affords indubitable proof that they are of a very ancient date; and we endeavour to account for the variations found in their style from that of other buildings of high antiquity, by supposing the artists of a Grecian colony to have been influenced by a capricious taste, which may have led them to deviate from the general practice of their masters in the mother Country.

The first is an hypæthral edifice 195 feet long, and 79 feet broad, measured on the top of the stylobata which supports it; it is hexastyle and peripteral, with fourteen columns on each flank, and in the thickness of the wall between the naos and pronaos, are steps formed for the purpose of ascending to the roof, or to the upper gallery of the naos; this gallery was supported by fourteen columns in the interior, seven on each side, at 8 feet from the walls, and above these is a plain entablature which supports an upper tier of columns of the same Order. Those of the exterior peristyle are 29.952 feet high, including the capitals, and the bottom diameter is 7.66 feet. The extreme triglyphs on each face are placed at the angles of the frize, as in all the ancient Grecian examples; but they project in front of the frize, which, as well as the architrave, is in a vertical plane passing through the face of the hypotrachelion. There are also triglyphs on the walls of the body of the Temple, and the ceiling of the pteromata coincided with the under surface of the inclining roof. The sides of the pediment are plain, and without an *epitithedas* or crowning moulding.

The second Temple is hexastyle and peripteral with thirteen columns in each flank; its length is 107.33 feet, and its breadth 47 feet, measured on the upper step. The pronaos is open on three sides, with four columns in front, and one on each side between those front columns and the pilasters of the naos; but the posticos is closed by a wall in front, as if intended to serve for an opisthodomus or sanctuary. The height of the columns is 20.354 feet, and the bottom diameter is 4.244 feet.

Instead of the annulets under the echinus, which, in almost every instance, occur in the Grecian Doric examples, there is here formed, at the top of the shaft, a sort of scotia; on the concave surface of which is sculptured round the column, a row of leaves whose tops incline forward, as if pressed down by the weight of the capital which they support; the echinus being placed immediately above them like a vase on the top of a plant. The face of the architrave is vertically over the middle of the shaft, and the extreme triglyphs have their centres corresponding with the axes of the columns; whereas, in every other ancient Grecian example, one of the vertical sides is in coincidence with the angle of the frize. This Temple is further remarkable for having no mutules in the cornice, and for the soffit of the corona being formed into rectangular *lacunaria*, or sunk panels, three deep.

The columns of the pronaos are shorter than those of the peristyles, and they have small bases, consisting of an astragal and fillet. There are triglyphs in the entablature of the pronaos, and the top of its cornice is on a level with the under side of the architrave of the peristyle.

At the same place are the ruins of what has been taken for a third Temple, and in the *Antiquities of Magna Græcia* it is described as such; we are, however, informed by artists who have recently visited this spot, that there are no traces of the walls of a cella to be found within the peristyle; and it is therefore probable that the edifice has been merely an open portico. On this account we think it right to give the description in another place.

As we endeavour to describe the Grecian Doric Temples according to their antiquity, we are brought, in the next place, to those of Athens, which are universally considered as affording the best specimens of the Architecture of the Grecian school. A full description of these celebrated buildings is contained in Stuart's *Antiquities of Athens*, and particularly in an augmented edition of that Work, with a supplementary volume, just published. In this Work, the joint production of several distinguished Architects, numerous mistakes, into which the author had fallen, are corrected, and the subjects are enriched with copious and learned notes.

The Temple of Theseus at Athens.

The most ancient, perhaps, of the Athenian Temples, is that which was dedicated to Theseus, and which is thought to have been erected a few years after the battle of Marathon, when the ashes of that hero were brought by Cimon to Athens.

This Temple, like the others, is of a rectangular form, of the kind called peripteral, amphiprostyle, and hexastyle, and has thirteen columns on each flank, including, as usual, the columns at the angles. Its extreme length is 104.244 feet, and its width 45.28 feet, measuring on lines circumscribing the exteriors of all the columns. The whole length of the side walls of the Temple is 74.06 feet, and the breadth between the exteriors of these walls is 25.78 feet. The side walls extend beyond the naos at each extremity of the Temple, forming a pronaos whose depth is 16.4 feet, and a posticos whose depth is 12.49 feet. These walls are terminated by antæ pilasters at the extremities, and between the pilasters, both of the front and rear, are two columns. The whole building is elevated on a stereobata, or general basis, to the top of which there is an ascent by two steps surrounding it.

The columns are fluted, as usual, and are without bases; their height is 18.735 feet, and the diameter at bottom is 3.304 feet. The height of the whole entablature is 6.846 feet, that is $\frac{1}{2.7}$ of the height of the column; the face of the architrave is in a vertical plane passing nearly through the circumference of the shaft at its foot, and those of the triglyphs are in the same plane.

The intercolumniations of this Temple are equal to 1.6 diameters, except those between every two outer columns on each side, which are rather less; and the breadth of the pteromata is 6.45 feet. The antæ pilasters are 3.19 feet broad; they have both capitals and bases, but their shafts have no diminution; the capitals do not resemble those of the columns, but consist of an abacus, under which is a bird's-beak moulding and an astragal; the base consists of an inverted cymatium above a low plinth.

The soffit, or ceiling between the front columns and the pronaos, is in a horizontal plane which passes a little above the top of the corona of the front columns; and the entablature over the front of the pronaos is continued to the interior face of the entablature of the flank columns. Seven rectangular projections below the ceiling, like beams of stone, each 1.575 feet broad, and 3.1 feet from each other, are placed in horizontal positions, extending from the front of the pronaos to the interior face of the entablature of the front columns, as if to support the ceiling above them. Their lower surfaces are on a level with the top of the frize; and between every two are sixteen lacunaria, or sunk panels, of a square form, disposed in two rows, to ornament the ceiling. The general ceiling of the interior is on the same level as that in front of the pronaos; but, below it, in horizontal positions, and in the direction of the breadth of the Temple, are other projections like beams of stone; the intervals between every two of which are ornamented with two rows of lacunaria similar to those before mentioned.

On the metopes of the Eastern front are sculptures representing the labours of Hercules. On the frize over the antæ of the pronaos, where there are no triglyphs, is the representation of some battle, probably that of Marathon, and over the antæ of the posticos are sculptured the combats of the Centaurs and Lapithæ. The whole building was covered by a pediment roof which is now destroyed. A plan and elevation of this Temple is given in pl. i. figs. 5 and 6.

The Temple of Minerva Parthenon at Athens.

When Pericles became possessed of the supreme authority at Athens, his own elegant taste, and perhaps the necessity of gratifying a people vain of their importance, led him to embellish the city with the most splendid edifices Art could construct. Phidias was then in the full enjoyment of the most exalted reputation, and, under his direction, the Temple of Minerva Parthenon, on the site of the more ancient Hecatompedon, was built by Ictinus.

The present Temple is of a rectangular form, its length is 228.7 feet, and breadth 100.8 feet, measured on a line circumscribing all the exterior columns. It is peripteral, hypæthral, and octastyle, having eight columns in front and seventeen on each flank, including the columns at the angles. The length of the body of the Temple between the exterior of the front and rear walls is 158.6 feet, and its breadth between the exterior and the side walls is 70.22 feet; the thickness of the front and rear walls is 6.658 feet, and of the side walls is 3.858 feet. The body of the Temple is divided into two unequal parts by a wall 2.917 feet thick; and there were doors of communication between them, the traces of which are still to be seen near the wall on each side: one of these divisions was 43.8 feet long, and the other 98.6 feet; the former was the opisthodomus or Treasury of the Temple, or, as some suppose, the public Treasury of the State; it was covered by a ceiling, and was divided into three parts by two rows of columns, two in each row; it had no windows in the walls, consequently it could only have received its light from the doors, unless there were windows in the roof. Mr. Stuart has, by mistake, placed six columns in this division of the Temple; but that there were only four is evident from the disposition of the circles on the floor which mark the places where they stood. The other division was a court enclosed by the four walls, and having its central part open to the sky. In the interior was a peristyle, probably of Ionic columns, at the distance of 14 feet from the walls on each of the four sides of the building, and the passage left between the columns and the walls was, probably, covered by a roof. On three sides of the Temple the pavement of this passage is sunk in the middle below that of the court; on the higher level, next to the interior of the court, are yet remaining the marks where the interior ranges of columns stood; and on the side of this division, which is furthest from the entrance, are seen the foundations of the pedestal which supported the statue of the Goddess; this pedestal appears to have been about 20 feet square.

The side walls were carried out five feet beyond the walls of the front and rear faces, and were terminated by antæ pilasters. There are no columns between the antæ, as in the Temple of Theseus, but there is a row of six columns parallel to the front and rear of the building at the distance of seven feet from the faces of the antæ. Between these columns and those of the front and rear faces is a space 12 feet broad, but the breadth of the pteromata, or spaces between the side walls and the columns of the flanks, is only 9 feet. The ceiling of the pteromata was level with the under part of the corona in front, and fragments of its soffit have lately been discovered, from which it seems to have resembled that of the Temple of Theseus, and to have been ornamented with lacunaria. Above the stones of this soffit came the masonry of the roof.

The whole Temple and the surrounding columns stood on a stereobata, or general basis, to the upper surface of which was an ascent by three steps; the walls of the Temple stood on another basis, the upper surface of which was the pavement of the interior, and to this was an ascent by two steps from the pavement of the pteromata.

All the columns are of the Doric Order; the height of those surrounding the Temple is 35.903 feet including the capital, and, except the four columns at the angles, their lower diameter is 6.15 feet. The columns at the angles of the edifice are rather thicker than the others, their lower diameters being 6.29 feet, and the shafts of all the columns are fluted with shallow channels which meet each other in longitudinal edges. The whole entablature is 11.192 feet high; that is, $\frac{1}{3.2}$ of the height of the column, and the faces of the triglyphs are in the same plane as that of the architrave. The antæ pilasters resemble those of the Temple of Theseus.

The columns and walls of the Temple incline, at top, towards the centre, so that the whole building assumes the form of a frustum of a pyramid. By accurate measurements, lately made, it appears that the faces of the abaci of the columns are vertical; those of the architrave and frize incline inward at top, but the parts which remain of the cornice incline outward, and the foot of the architrave is in a vertical plane passing through the circumference of the foot of the shaft. All the metopes are enriched with sculpture representing the combats of the Centaurs and Lapithæ, and on the frize of the wall enclosing the body of the Temple, which has no triglyphs, was sculptured a Panathenaic procession. The two pediments were, also, filled with exquisite sculpture; that on the Eastern pediment represented Jupiter receiving Minerva in an assembly of the Gods, and that on the Western pediment expressed the contest of Minerva and Neptune. The epitithedas, or crowning moulding of the pediment, which is in the form of an echinus, is terminated at each lower extremity by a lion's head which is not perpendicular to the faces of the walls, but inclined towards the opposite extremity of the building.

The roof of the Temple was covered with flat marble plates, the lateral junctions of which formed a number of parallel lines extending down the sloping sides of the roof: from the general ridge of the building to the tops of the flank walls, and along the top of the cornice on each flank was a row of fleurons, or honeysuckle ornaments at certain distances from each other but not always

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re.

corresponding with the extremities of the lines above mentioned.

The shafts of the columns, instead of being exactly frusta of cones, have a certain entasis or swell, so that a longitudinal section through the axis is bounded on each side, not by a right line, but by a curve concave towards the axis. This form, which was long supposed to be peculiar to the Roman columns, was first observed, by Messrs. Allason and Cockerell, to exist in a Grecian example, in the columns of this Temple, and it has been subsequently ascertained that a similar entasis exists in other examples of the Grecian Doric Order. The curvature of the section appears to be continuous from the top to the bottom of the shaft, as if it were part of a circle of very large radius, the centre of which is in a horizontal line passing through the foot of the axis. In general, however, the deviation of the shaft from a conical form is scarcely perceptible to the eye; and it, therefore, easily escaped the notice of previous travellers.

The appearance of this Temple must have been extremely brilliant from the paintings with which it was adorned. The abaci of the capitals of the columns, the tenia or fillet of the architrave, and the capitals of the triglyphs and metopes were all embellished with a painted fretwork, and the regulæ under the triglyphs with inverted palmettes and honeysuckles. In the sloping sides of the pediments the epitithedas and the mouldings below it, also the bird's-beak in the bed moulding, were painted with oves. On the architrave of the principal front, under every metope, were bronze shields or circular plates attached by metal cramps, and, between them, are as many holes to which metal ornaments or inscriptions were attached, so that the stonework could hardly have been seen. On the other three sides there were circular plates over each column only. Between the columns of the hexastyle or inner portico is a marble sill, in which was, at one time, inserted a metal railing.

Beneath the marble steps surrounding the present Temple are seen the substructions of the ancient Hecatompedon, consisting of a rusticated basement of freestone. And below the interior of the Temple have been found many fragments, among which are parts of an Ionic architrave having three faciæ, a proof that this Order had been employed before the time of the erection of the present Temple. In the walls of the Acropolis are immense fragments of a Doric entablature, executed in freestone, nearly similar to that of the Parthenon, and frusta of columns, all of which are supposed to have belonged to the Hecatompedon. These ancient columns have channels, cut at top and bottom only, about 10 inches long, the rest of the shaft being plain. Besides these splendid examples of the Doric Order, there exists in the Agora at Athens, a tetrastyle portico of the same Order, executed in the ancient manner; but it is supposed, by Stuart, to have been part of a Temple dedicated to Rome and Augustus.

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At Bassa, near Phigalia, in the Peloponnesus, are the remains of a peripteral Temple dedicated to Apollo Epicurius, of the Doric Order, with six columns in front and fifteen on each flank. This Temple, the length of which is 121.3 feet, and breadth 43.5 feet, measured between the centres of the extreme columns, is remarkable both from its position and construction; instead of lying in a direction nearly East and West, as is usual with the Grecian Temples, it lies nearly North and South, and from the interior faces of the walls of the cella project five piers on each side, to the extremities of which half columns of the Ionic Order were attached; all these piers are perpendicular to the faces of the walls, except that at one extremity of the cella there is one on each side which stands obliquely with respect to those faces; and between these two is an isolated column of the Corinthian Order. The time of its construction is unknown, and the employment of Ionic and Corinthian columns in the interior would lead us to suspect that that part of the building may have been erected subsequently to the peristyle, which bears marks of the best Age of Architecture in Greece; but the masonry of the whole Temple is so united together as to leave no doubt that all the parts are of equal antiquity.

Part I.

Rhamnus,

At Rhamnus, in Attica, are the remains of two Temples of the Doric Order, one of which, dedicated to Nemesis, was peripteral and hexastyle, with twelve columns on each flank. All the columns are fluted at top and bottom only, the rest of the shaft being plain, and the soffits of the ceiling of the pteromata and porches are ornamented with lacunaria. Nearly in contact with this, is the apteral Temple of Themis, which consists of a cella and one porch only, with two columns of the Doric Order between the antæ. The columns are of a soft, porous stone, but the walls are of marble, the blocks of which are polygonal prisms of unequal sides. These, together with the Temples of Minerva at Sunium and of Jupiter at Nemea, between Argos and Corinth, appear to have been built in the time of Pericles. They were all of the Doric Order, and each had six columns in front, but their dimensions cannot now be ascertained.

and Delos.

In the Island of Delos are some remains of what is supposed to have been a Temple of Apollo. It is of the Doric Order, but at what time erected is unknown; it possesses, however, some peculiarities of form which lead to an opinion that it was at a late period of the Grecian school.

The height of its columns is 18.72 feet, and the lower diameter is 3.092 feet; consequently the height of the column is about six diameters. The height of the entablature is 5.875 feet, or about $\frac{1}{3.2}$ of the height of the column.

The shaft is plain, except near the top and bottom, where the circumference is cut in channels about one foot long, as in the columns of the Hecatompedon: the plain part is rather larger in diameter than that which is fluted, and the echinus in the capital is nearly in the form of an inverted frustum of a cone. The face of the architrave is in a vertical plane which, if produced downward, would intersect the shaft in about the middle of its length, and the faces of the metopes coincide with that of the architrave.

Temple at Cora.

At Cora, in the Ecclesiastical States, are the remains of a Doric Temple supposed to have been dedicated to Hercules, and to have been built while the South of Italy was under the dominion of the Grecian Colonists; but, perhaps, not long before the Romans obtained possession of the Country. The columns of this Temple are eight diameters high, and consequently the Order is much lighter than that employed in the buildings of Greece or Sicily; the shaft is of a polygonal form up to one-third of the height, and the remainder is channelled; the base consists of a simple torus without a plinth, and the capital is formed by an abacus placed over a moulding, the vertical section of which has the form of a quadrant of a circle instead of an echinus. There are triglyphs in the frize, but, between every two columns, there are three of these ornaments, whereas the earlier Greeks introduced but one or two.

Herculaneum and Pompeii were, originally, towns built by colonists from Greece, and the style of Architecture in those places is decidedly Grecian; the buildings are mostly of the Doric Order, and the proportions employed in the columns and their entablatures are nearly the same as those of the Order at Cora. The lightness of the shafts and the forms of the capitals of the columns above-mentioned seem to afford ground to believe that the Orders employed at all these places are intermediate links connecting those of the ancient Greeks with the Orders afterwards adopted in Roman buildings.

CHAPTER V.

Description of the Grecian Ionic and Corinthian Temples.

We have seen that, according to Vitruvius, the Ionic Order originated in Asia Minor, and that the first Temple built in that style was in honour of Diana. However this may be, it is certain that the Order prevailed chiefly in the Asiatic States of Greece, and it was not till long after its invention that it was much employed in Europe.

The triple Temple at Athens.

There existed in Athens, at an early period, a Temple dedicated to Minerva Polias and to Erectheus, which is supposed to have been partly destroyed at the time of the Persian invasion; and, from a passage in Xenophon it seems that the destruction was completed by a subsequent fire in the XCIIId Olympiad, or about 408 years before Christ. The present Temple appears to have been erected upon the ruins of the old one, by Philocles, of Acharnæ, probably during the Peloponnesian war: it is threefold, dedicated to Minerva Polias, to Erectheus, and to Pandrosus; and it is considered as the best example of the Ionic Order that has ever been executed.

The body of the present building is of a rectangular form, 74.52 feet long, and 38.39 feet broad, measured on the exterior of the upper step; this was divided into two parts by a wall perpendicular to the length of the Temple; the division at the Eastern end was that dedicated to Erectheus, and the division at the Western end, to Minerva Polias. A projection was made on the Southern side close to the Western extremity, which formed the small Temple appropriated to Pandrosus, and a corresponding projection was made at the Western extremity on the Northern side, in order to serve as a common porch to the two last-mentioned Temples.

The pavement of the Temple of Erectheus is elevated about two feet above the general level of the ground on the Eastern and Southern sides of the building, and it is ascended by three steps which extend along those sides. On the Western and Northern sides of the spot occupied by this Temple the ground falls abruptly, so that the pavement of the Temples of Minerva Polias, of Pandrosus, and of the Northern portico is about nine feet lower than that of the former Temple.

In front of the Temple of Erectheus is a portico of six Ionic columns, the centres of which are 6.425 feet from the face of the wall. At the Western, or opposite extremity of the building, are four half columns of the same Order, projecting from the wall, but their lower extremities are 3.15 feet below the level of those of the columns at the Eastern end, and about 13.75 feet above the ground on this side. On the interior side of this Western wall are four pilasters placed exactly at the backs of the columns, and between the columns and pilasters are three windows which give light to the passage leading to the Temple of Pandrosus. One general roof, with sloping sides, served for the whole of the double Temple of Erectheus and Minerva Polias.

The Northern portico is 34 feet long from East to West, and 20 feet wide, but the Western flank projects 7.5 feet beyond the Western end of the whole building. It has four columns in front, with one on each flank between the front columns and the pilasters which are attached to the wall of the building. This portico was covered by a pediment roof, and the top of the cornice of the portico was on a level with the under surface of the architrave of the main building. A doorway opposite the centre of the portico leads to the passage before mentioned, which may be considered as a pronaos to the Temple of Minerva Polias, and which was separated from that Temple by a wall. At the opposite side of this pronaos was a doorway leading to the small Temple of Pandrosus, whose length is 19 feet from East to West, and breadth is 11.5 feet; the Western flank coinciding with the Western end of the main building. It consists of a flat roof, supported in front by four female figures, which, in such a situation, are denominated *Caryatides*; and there is one on each side between the front figures and the pilasters, which are attached to the wall of the Temple of Minerva. The figures are 7.087 feet high, and stand upon a *podium*, or low wall, which encloses the area of the Temple. The height of this podium is 5.683 feet, and it stands on three steps, which elevate the pavement about 2.37 feet above the ground. The entablature of this Temple is 2.963 feet high, and the top of its cornice is on a level with the middle of the architrave of the portico of Minerva Polias. The soffit, or ceiling, is ornamented with square, sunk panels, three deep, the sides of which are in the form of inverted steps.

The departure from the general simplicity of the Grecian Temples which we observe in this edifice, seems to have been rendered necessary by the nature of the ground and the disposition of the neighbouring buildings; which anciently, perhaps, approached very near the Temple, and prevented the view of it except from three points, where as many streets led to the site it occupies. Opposite each of these three openings a portico was formed, seemingly with the design of affording a grand termination to the view on approaching the Temple along the street. The manner in which the masonry of the three porticos is connected with the body of the building proves that the whole edifice was erected, as it is now, at one time.

In the portico of the Temple of Minerva Polias, the columns are 25.822 feet high, of which the base occupies 1.108 feet, and the capital 1.954 feet, measuring from the astragal below the volutes to the top of the abacus. The diameter of the shaft at bottom is 2.786 feet, so that the height of the whole column is equal to 9.27 diameters; the difference of the upper and lower diameters is $\frac{1}{5.6}$ of the latter, and the difference of the semi-diameters is $\frac{1}{9\frac{2}{3}}$ of the length of the shaft.

The capital consists of a sculptured echinus, and on two sides it has volutes, the faces of which, on each of those sides respectively, are in a plane parallel to the front of the portico; above these is a square abacus, the sides of which are cut in mouldings. The base is of the kind iec- e.

called *Attic;* that is, it consists of two tori with a scotia and fillets between them; the lower torus is plain, and the upper is sculptured with an ornament called a *guilloche.* None of the bases of the columns of either Temple have plinths. The shaft is fluted or cut in twenty-four channels, which do not join in a single edge as is the case with almost every Doric column, but have a narrow fillet or flat surface between every two; in order, no doubt, to render them less liable to be broken when, as in the present case, the channels are deeply cut in the shaft.

The taste of the Greeks for ornamenting their Architectural works was displayed to great advantage in this Temple; for, between the spiral mouldings in the volutes of the capitals are cut channels, which were once filled with gilt bronze ornaments or mouldings in similar curves; and ornaments of the same material were placed in the angles between the curves of the volutes and the top of the shaft, in front, which must have considerably increased the effect of the sculpture. Glass eyes of various colours were also fixed between the curves which form the guilloche in the capital.

The height of the entablature is 5.513 feet, which is $\frac{1}{4.7}$ of the height of the column, and the intercolumniations are equal to 3.5 diameters.

The antæ pilasters, which are placed at the extremities of the walls, have bases similar to those of the columns, but the tori are fluted horizontally; the capitals have no volutes, but the hypotrachelion and an echinus moulding above it correspond with those in the capitals of the columns, and are similarly ornamented; above the echinus is a cymatium which supports the abacus. The heights of the pilasters are equal to those of the columns, but their breadths are less than the diameters of the latter, being equal to 2.4 feet, and their shafts have no diminution.

The architrave of each of the three buildings is divided horizontally into three faciæ, every one of which projects a little way over the one below it; and Mr. Mitford thinks this is the oldest Temple existing in which such a division was made, but we have shown that a similar architrave must have formed part of some Temple more ancient than the Parthenon itself. The frizes of the Temples of Erectheus and of Minerva Polias are plain, and the corona has its under surface excavated. In the Temple of Pandrosus there are dentels, which rest immediately upon the architrave, and seem intended to supersede the triglyphs of the Doric Order.

The columns of the Temple of Erectheus are similar to those of Minerva Polias, but on a smaller scale; their height is 22.554 feet, and the lower diameter of the shaft is 2.317 feet. The capitals of the columns of both Temples are very much alike, but the bases of the former are less elegant than those of the latter; the lower torus being smaller, and the upper one channelled horizontally, which gives the base a confused appearance. The execution of the portico of this Temple does not appear to have been performed by the same hand as that of Minerva Polias, and is much more coarse; the volutes are tame, and the sculptures rude. Fig. 1. pl. vi. is a general plan of the triple Temple; figs. 2 and 3 are elevations of the hexastyle portico, or that of the Temple of Erectheus, and of the front of the Temple of Pandrosus. Fig. 1. pl. vii. is an elevation of one of the columns of the tetrastyle portico, or that of Minerva Polias.

Part I.

Temple on the Ilyssus.

A specimen of the Ionic Order, which united considerable beauty with simplicity, was that found in an apteral Temple, the remains of which lately existed on the South bank of the Ilyssus near Athens. This Temple was supposed by Mr. Stuart to have been built in honour of the hero Panops; the date of its erection is unknown, but, probably, it was about the time of the Peloponnesian war. It was of a rectangular form, and amphiprostyle, with four columns both in front and rear. Its whole length was 41.623 feet, its breadth 19.532 feet, and the body of the Temple was divided into two parts by a wall separating the naos from the pronaos. The height of the columns was 14.693 feet, and the diameter of the columns, at the bottom of the shaft, was 1.783 feet. The height of the entablature was 3.606 feet, or about one-fourth of the height of the column, and the frize was adorned with sculpture.

The bases of these columns were of the Attic kind, but deficient in elegance; the scotia was high and shallow, and the upper torus fluted horizontally. The extremities of the side walls were terminated by pilasters, the bases of which were similar to those of the columns; except that the lower torus was smaller; the capitals resembled those on the pilasters of the Erectheum, but the mouldings were quite plain; like all the Greek antæ, the breadths of these were rather less than the diameter of the columns, and the shaft had no diminution. It is much to be lamented that this building, which was in good preservation in Stuart's time, is now entirely destroyed, and that not a vestige remains of the ruins.

Ionic Temples in Asia.

The famous Temple of Diana at Ephesus was of the Ionic Order, but we only know that it was 425 feet long, and 220 feet broad, that the columns were 60 feet high, and that it was of the kind called dipteral, having two rows of columns along each flank. This Temple was designed by Ctesiphon, and burned by Eratostratus three hundred and thirty-six years before Christ. It was the wonder of Asia, and is said to have been four hundred years in building, though all the Greek cities of Asia contributed to the expense.

Soon after the Persian invasion of Greece, it is probable that the Temple of Bacchus was constructed at Teos. Vitruvius shows that it was built by Hermogenes, that it was of the Ionic Order, with eight columns in front, and that it was of the kind called pseudodipteral. He further adds, that this Architect was the inventor of that style of building, by leaving out the interior of the two ranges of columns which surround the dipteral Temples, in order to afford spacious walks between the columns and the walls. This building is now completely in ruins, so that no vestige of the plan can be discovered; but, from the fragments which remain, the form and dimensions of the columns and architrave have been fully ascertained. A description of them is given in the *Ionian Antiquities.*

The once magnificent Temple of Apollo Didymeus near Miletus, was of the same Order, and is supposed to have been built about three hundred and eighty years before Christ. It is almost entirely destroyed, but travellers have succeeded in ascertaining that the extent of the Western front was nearly 163 feet, and it appears to have been of the kind called dipteral. The columns of the interior range are fluted through the whole length of the shaft, but those of the exterior range, only to about two feet below the capital; from which circumstance it seems probable that the Temple was never finished.

The Temple of Minerva Polias at Priene appears, by an inscription, to have been dedicated by Alexander the Great, probably on being rebuilt after it had been destroyed by Xerxes. The authors of the *Ionian Antiquities* show, from the ruins, that the Temple has been peripteral, and surrounded by a *peribolus* or enclosing wall. The eyes or centres of the volutes appear to have been bored, as if for the convenience of fixing festoons, and the faciæ of the entablature incline forward at top, both on the exterior and interior of the colonnade. This is the last existing specimen of the Grecian Ionic Order whose age can be depended on; and the ruined state of this and the preceding Temple renders it impossible to show the proportions of the column and entablature, the bases and capitals of some of the columns being all that remain entire.

At what time the Corinthian Order may have come in use.

We have mentioned the circumstance which is said to have given rise to the invention of the Corinthian Order; and, though the story is doubtful, and there is reason to believe that the capital of this Order had been employed at an earlier period, yet it is probable that it might not have come much into use till the time of Callimachus; that is, towards the conclusion of the Peloponnesian war. About that time, it appears that the hypæthral Temple of Minerva at Tegea was built by Scopas, an Architect of Paros, the interior of which, according to Pausanias, was adorned with columns of the Corinthian Order. Unfortunately this superb building, as well as the city itself, is completely destroyed, and the ruins, if any remain, are so deeply buried, that it is not likely any information can ever, now, be obtained concerning it.

The Temple of the Winds at Athens.

No example of this Order remains, of a truly Grecian origin, which can be called a Temple; unless we are allowed to consider as such, the edifice at Athens built by Andronicus Cyrrhestes, an Astronomer of that city, in honour of the eight principal Winds. It is the general opinion that this building was erected about the time of Alexander the Great, though the character of the mouldings and sculpture has, by some, been thought to indicate the Age of Hadrian. This Temple, or Tower, is of an octagonal form, having four of its sides made to face the four cardinal points of the horizon, and the others, to face the four intermediate points. The length of each side, on the exterior, is 10.8 feet, and both on the North-Eastern and North-Western faces is a doorway, with a porch in front, having a pediment roof, supported by two columns of an Order which some have been pleased to call Corinthian, but which others have proposed to call the Attic Order; and attached to the wall, on the Southern side of the building, is a tower in the form of a segment, equal to three-quarters of a cylinder, the diameter of which is 9.7 feet on the exterior. The general pavement is raised on three steps, each one foot high, and in the centre is a well with small channels cut about it, probably to serve the purpose of a *clypsedra*, or water-dial; being, perhaps, supplied with water from the circular building before mentioned.

Each external face of the building is quite plain up to the height of 29 feet from the top of the steps; at this height is a moulding which surrounds the building, and, above it, upon the different faces, are sculptured the figures of the eight Winds. The walls terminate in a general entablature, consisting of an architrave, frize, and cornice, which together are equal in height to 4.229 feet, and the top of the cornice is 7.937 feet above the moulding before mentioned. The diameter of the Temple is less at top than at bottom, so that it has the appearance of a frustum of a pyramid; and the whole is covered with a pyramidal roof 4.375 feet high, consisting of one block of marble resting on the walls and having its exterior cut in the form of tiles. Above this, according to Vitruvius, was a brazen Triton, holding a rod in his right hand, and capable of turning with the wind so as to point toward the figure of the Wind at that time blowing.

In the interior of the building, are three cornices along the periphery of the wall, and projecting from it. The lower one is 5.68 feet from the pavement, and consists of one plain facia with a moulding at the top. The middle one is 8.637 feet above the former; it consists of sundry mouldings, and is supported by modillons which project from the wall, and have their under surfaces cut in the form of a scroll or curve of contrary flexure; in the soffit of this cornice are panels of a trapezoidal form sunk between the modillons; and between the mouldings on the front of the cornice is a row of dentels. The third cornice is 11.475 feet above the last, and quite plain; this supports eight small columns resembling those of the Doric Order, and these support the internal cornice of the whole building.

Mr. Stuart observes that the capitals he has given to the columns of the porches were found about the building, but he doubts whether they ever belonged to it; however, as such capitals are abundant in Athens, and other parts of Greece, they may serve as specimens of an Order which approaches very near the Corinthian. Each capital consists of a row of lotus leaves surrounding the vase, and reaching from bottom to top; about these, at bottom, is another row, about half the height of the former, and consisting of clusters of leaves, resembling those of the olive. An elevation and plan of these buildings are given in plate vi. figs. 4 and 5, and an elevation of one of the columns in plate vii. fig. 5.

The T
of Ju
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Athen

One of the most superb Temples of antiquity was that of Jupiter Olympius at Athens, which was begun in the time of Pisistratus. The work, however, was interrupted by his death, and by the troubles in which the State was, subsequently, involved; and it appears from what Vitruvius says, in the Proem to the VIIth Book, that it was finished by Cossutius, a Roman Architect, in the time of Antiochus, that is, about 400 years afterward: but as the Emperor Hadrian is also said to have finished the same building, it is probable that some of the ornamental parts were not added till the time of that Monarch.

The columns of this Temple are of the Corinthian Order, 6 feet in diameter and 60 feet high, of Pentelic marble, with Attic bases and fluted shafts, but, as they were probably put up by Cossutius, they cannot be considered as specimens of the Grecian style. The Temple was rectangular, dipteral, hypæthral, and decastyle, having ten columns in front and twenty-one on each flank. The body of the Temple, measured on the exterior, was 259 feet long and 96 feet wide, and was divided into two parts by a wall; one of these divisions was covered by a roof; the central part of the other was open to the sky, and was surrounded by an interior peristyle. The side walls of the Temple were continued beyond those of the front and rear, and were terminated by a column at each end. Between these were four other columns, and there were three rows of columns beyond them, at both extremities of the Temple. The whole length of the Temple was 354 feet; its width 171 feet, measured on lines circumscribing all the exterior columns, and it was surrounded by a peribolus or enclosure, of a rectangular form, 679 feet long and 463 feet wide.

Many other examples of this Order might, perhaps, at one time, have existed in Greece, but it is highly probable that the columns were transported to Italy by the Romans when they became possessed of the Country.

CHAPTER VI.

Description of the Civil Edifices of Greece.

The *Propylea*, or entrances of the Grecian cities, were, usually, adorned with Architectural embellishments; and those of Athens and Eleusis have been particularly remarkable for their grandeur. We, therefore, think it may be acceptable to give a short description of these buildings.

The Propyleum of Athens is situated on the Western side of the Acropolis, on an ascending ground, commanding an extensive view towards the Gulf of Corinth, and lying in a direction from West to East. On account of the form of the ground, the horizontal pavement is divided into three parts; and steps, extending across the entrance from North to South, afford an ascent from one level to the next. On approaching the Western front of the building there is, according to Stuart, an ascent to the first pavement by a flight of steps about 80 feet long, with a pedestal or pillar of masonry on each side of them; but it has been since observed that the one on the Southern side of the steps, certainly, never existed; for its place is occupied by the substructure of a small Temple, which is now thought to be that of Victory, without wings; and the existence of even the steps themselves is uncertain, as the spot on which they were supposed to have been placed, has been long occupied by a Turkish battery. The upper part of the pedestal on the Northern side of the ascent is, decidedly, of Roman construction; but, from its appearance, it is possible that the lower part may have been more ancient.

The pavement before mentioned is of a rectangular form, about 78 feet long from North to South, and 40 feet wide. On the Eastern side, three steps, extending the whole length of the pavement, led to the next platform, which is three feet higher than the other, and on this is the body of the building. The plan of this is a rectangle, 66.5 feet wide from North to South, and 42.25 feet long, within the walls which enclose it on the Northern, Southern, and Eastern sides; it has a magnificent portico of six Doric columns before the open entrance on the West, which makes the whole length of the building equal to 54 feet from the front of the columns to the interior of the Eastern wall. This part was, originally, covered by a roof, which, together with the cornice of the portico, is now destroyed. The architrave and frize remain, and we find that the metopes of the latter were adorned with sculpture.

The interior of the building is divided into three passages, directed from West to East, by two rows of columns, two in each row, (Mr. Stuart places three in each row, but this is a mistake,) and, from the fragments which have been found in the walls, it appears that the columns were of the Ionic Order, that their capitals resembled those in the Temple of Erectheus, and that they had Attic bases. Within this portico may be seen vestiges of an inclined plane, with traces of ruts cut in the rock, to enable the cars to ascend towards the citadel.

The foot of the Eastern wall is elevated above the pavement of the building, and there is an ascent to it by five steps leading to the third pavement, which is five feet higher than the former. In this wall are five doorways which lead to the interior of the Acropolis, through another portico of six Doric columns, which forms the Eastern extremity of the whole building. About the three centre doorways are false lintels and jambs; and above them were cornices, supported on consoles, of which some indications remain on the walls, together with various holes for the insertion of metallic ornaments. The length of this portico, from North to South, is the same as that on the Western front, and its depth, from East to West, is 26.5 feet, not including the thickness of the wall just mentioned, which separates it from the principal building. This portico also was covered by a roof with a pediment facing the East, but the roof was higher than that of the rest of the edifice. At the foot of the columns of the Eastern portico is one low step descending towards the citadel, in order, probably, to prevent the rain water, from it, running down into the Propyleum.

On the right and left of the first, or Western platform, is a building of the Doric Order with three steps in front, which are placed on a blue marble band, considerably elevated above the platform. That on the left was divided into two parts by a wall, from West to East, in which was a door and two windows. In front of its pronaos are three Doric columns between antæ, and the sides of the windows on the interior are ornamented with short pilasters. The length of the whole is 55.75 feet from North to South, and the width is 41 feet, on the exterior of its walls.

This is supposed, by Mr. Stuart, to have been the Temple of Victory without wings, but, by later travellers it is considered as a simple chamber. Mr. Stuart also supposes that there was a building similar to it on the Southern side of the platform, and he considers this as the saloon which was decorated with the paintings of Polygnotus; but, it is evident that it could not have had the same length as the opposite chamber, unless its extremity had been raised on substructions carried out from the rock, of which no indications appear. There is not even any vestige of a wall on the Western front of the Southern building, and it is probable that no such wall existed. Both these wings seem to have been crowned by pediments, as a fragment of one has been found under that on the Northern side; and it has been supposed that there were small colonnades on that side of the two wings of the Propyleum, which faces the citadel. The wings undoubtedly formed part of the original structure, as the masonry of both is inserted in that of the central building.

The columns of the Western portico are 28.667 feet high, of which the capital occupies 2.304 feet, and the upper diameter is 3.917 feet. The columns of the Eastern portico are 28.798 feet high, to the top of the capital, which is in a horizontal plane, coinciding with the ceiling of the principal building, or a little above the top of the architrave of the Western front. The pedestals of the columns within the Propyleum are 5.25 feet high, which brings the foot of their bases on a level with the pavement of the Eastern portico. The columns are 27.167 feet high, including the bases and capitals, and the tops of the capitals are on a level with the top of the architrave of the Western front; their upper diameter is 2.858 feet, and their shafts are fluted.

The height of that which is called, by Stuart, the Temple of Victory, and of the building on the opposite wing is 25.596 feet from the pavement to the top of the cornice. The columns are 19.196 feet high; and the upper diameter 2.729 feet, and the height of the entablature is 6.397 feet. The antæ pilasters of these two buildings are 3.027 feet broad, and their shafts are without diminution.

Under the present Propyleum have been found the substructions of a more ancient entrance to the Acropolis. But in front, where the inequalities of the rock must have rendered it necessary to form additional works for the purpose of carrying the roadway, no remains of any such works exist; it is, therefore, probable that they have been removed at some succeeding time. In the Northern wall, under the right wing, are the appearances of what some persons have supposed to be a triple entrance. It is, however, probable that they are but the intervals between buttresses supporting the wall of the building on this side; for, besides being too narrow, the sides of the buttresses are left in steps, and have not been made smooth, as the sides of gates would have been. A low, continuous wall is carried out from the ends of the steps in front of the Northern wing of the Propyleum, nearly as far as the pedestal; but Mr. Stuart is wrong in making a gateway through it, for no such thing appears.

This superb edifice was constructed by Mnesicles between the years 437 and 432 before Christ, and during the time that Pericles possessed the Government of Athens.

The Propyleum of Eleusis.

The Propyleum of Eleusis is now totally destroyed, but from the account published in the *Unedited Antiquities of Athens*, it appears to have been, in some respects, similar to that which has been just described, being formed by two lateral walls, 60 feet asunder and 50 feet long, with a hexastyle portico of Doric columns both on the Northern and Southern fronts. There were five portals in a transverse wall, which led to the interior of the town, and, between the Northern front and the wall, was a double row of Ionic columns, three in each row. These columns resembled those of the Temple on the Ilyssus, and had Attic bases, of which the upper torus was fluted horizontally; the tops of the abaci were on the same level as the tops of the architraves in the entablatures of the porticos.

After passing through the Propyleum, there was found a peribolus, in the form of an irregular pentagon, enclosing a Temple of Ceres. The entrance to this enclosure was by a smaller Propyleum, or vestibule, about 48 feet in length, and as much in width; in the interior extremity of which were three portals formed by the side walls and by two intermediate piers; and in the middle of this vestibule, opposite the pilasters by which the piers are terminated, were two Ionic columns, similar to those of the Temple on the Ilyssus, with plain Attic bases, and an entablature only ornamented with dentels in the cornice.

The Temple of Ceres was nearly a square on the plan, and the length of each side was equal to 180 feet, exclusive of the portico, which was on the Western front, and consisted of a single row of twelve Doric columns, with shafts quite plain, except very short flutes at top and bottom. In the interior of the Temple were two double rows of columns, in directions parallel to that of the portico, which is contrary to the general practice of the Greeks. When this ruin was measured, a fragment of one column alone retained its original position; the places of the others were ascertained by the holes in the pavement, which were intended to receive the plugs connecting it with the lower part of the shaft; a situation in which plugs are rarely found, though they are frequently found at every joint of the stones in a column. This pavement, being below the level of that in the portico, seems to indicate that it belonged to a crypt or subterranean chamber. Plutarch speaks of lower columns in the interior of this Temple, and, hence, it is probable that there must have been a double range, one above the other.

A little in front of the grand Propyleum was a Temple of Diana, consisting of a naos and pronaos, with no other columns than two between the antæ. The Temple was of a rectangular form; its cella 24.5 feet long and 16 feet wide, and the ascent to the pavement was by five steps. The columns were of the Doric Order and fluted, and the triglyphs returned quite round the flanks. In other Grecian Temples the roof terminates in *stillicida*, or dripping eaves, but in this, the cymatium, or upper moulding of the pediment cornice, was continued along the flanks, and a channel was hollowed in it, for the purpose of collecting the rain from the roof; which was then discharged by the lions' heads sculptured at intervals along that moulding.

The external appearance of the dwelling-houses of the ancient Greeks seems to have been very simple, the Republican spirit of that people not permitting any of the Nobles to have their residences superior to those of the generality of the citizens; and it being thought highly indecorous to attempt, in the habitations of individuals, to rival the Temples of the Gods. Nothing remains, in Greece, of this class of buildings at the present day, and the only account we have of them is that which Vitruvius gives us, in the Xth Chapter of his VIth Book, where the internal disposition is said to have been made in the following manner.

The house was divided into two principal parts; one, called *andronitidis*, contained the apartments appropriated to the male part of the family, and the other, called *gynæconitis*, contained those appropriated to the women; the latter occupied the Southern, and the former the Northern side of the building. The entrance is described as a narrow passage on the Southern side, and having a stable and servants' room situated, one to the left and the other to the right hand of it. After getting through the passage, there was found an open quadrangle, the Southern side of which consisted of the apartments just mentioned; on the right and left hand were the *thalami*, or chambers. This quadrangle constituted, generally, an interior peristylium, being surrounded by columns within the walls, on the four sides. A long passage on the exterior of the thalami, and on the Eastern and Western sides of the building, separated them from other apartments, which, being destined for the reception of strangers, were called *xenodochia;* and these passages, from their situations between the *aulæ*, or courts, were called *mesaulæ*. On the Northern side of the peristylium was a covered space, opposite to the entrance, called *prostas*, which served as a porch, and had, on each side, an apartment, of which one was called *thalamus*, and the other *antithalamus*. At the extremity of the prostas was a passage leading to a vestibule, and from thence to a peristylium larger than the former. On either side of this passage were the *œci*, or apartments in which the mistress of the family dwelt. On one side of the vestibule was a dining-room, or *triclinium*, so called, probably, from its containing a triple couch for the company at meals; and, on the other, a painted room, or room for pictures, called *pinacotheca*. The peristyle last mentioned formed the centre of the men's apartments; on the Eastern side of it were the libraries, and on the Western side the *exedræ*, or places for study, conversation, and exercise. The Northern side was occupied by the *œci*, or apartments for the master of the family, and a vestibule in its centre led to a portico, which formed the exterior of the building towards the North.

From the dwelling-houses of the Greeks we may proceed to describe, in a few words, the disposition of the parts of their Theatres. The form of these buildings on the exterior was nearly semicircular; they were generally situated on one side of a hill, and the seats of the spectators occupied its declivity; or if a solid rock served for the basis of a Theatre, the seats were formed by cutting its mass in the shape of steps; of which kind of Theatre there are several still in existence, but reduced to heaps of ruins.

These seats, or steps, were divided at intervals by broad flat surfaces, or landing-places, concentric with the steps; these were by the Greeks called *diazomata;* and at the top of the steps was a colonnade, within which also were steps, serving as seats for spectators. Vitruvius prescribes that the upper edges of all the steps and diazomata should be in one right line, and he says that under the steps, in various parts of the building, were left vacuities, in which were put *echeia*, or brazen vessels, in order to increase the effect of the voices of the performers.

The curve formed by the lowest range of seats, or steps, was exactly equal to three-quarters of a circle, and within this curved line was a level space, which the Greeks called the *orchestra*, on which the dances were performed.

Beyond the chord line which limited the orchestra, was a level stage, raised about 10 or 12 feet above the orchestra, on which the actors performed their parts; this was called the *logeion*, and it was terminated by the *scena*, or wall against which the scenes were exhibited. Its length was nearly equal to the internal diameter of the Theatre, and its depth was limited by the circumference of the circle formed by completing the curve of the lower step surrounding the orchestra.

The height of the scena depended upon the magnitude of the Theatre, and it is described by Vitruvius as equal to that of the colonnade on the top of the seats. Three doors were formed through it, of which the central one was for those performers who represented the citizens, and the other two for such as personated strangers; an arrangement which accorded with that prescribed for the entrances of private houses.

The colonnade at the top of the steps was roofed over, but the rest of the Theatre was without cover, except that a great piece of cloth was occasionally drawn over, to protect the spectators from the heat of the sun, or from a shower of rain. If a heavy rain took place, it was necessary to suspend the performance, and the spectators retired to a covered portico behind the scena. Among the Ancients, the Theatrical representations took place by daylight.

The dramatic performances in the Greek Theatre were of three kinds; *viz.* Tragedy, Comedy, and Satire, and to each of these a particular kind of decoration was adapted. For Tragedy, the scene represented Palaces and Temples, of magnificent forms; for Comedy, streets with private dwelling-houses; and for Satire, were painted all the circumstances of a rural prospect. And to exhibit these different subjects, when required, there were placed, in vertical positions, in front of the wall of the scena, triangular prisms of wood, called *periactoi*, because they turned on axes: on each side of these was a painting, representing some part of one of the scenes which it was intended to exhibit, and when the parts relating to one subject were, by the revolution of the periactoi, brought into a plane surface, the scene was complete.

Gardens and promenades were made about the Theatres, for the entertainment of the company before and after the performance.

The nature of the Greek Theatre can be learned only from the description of Vitruvius; as no building of that kind exists entire in Greece, of an Age earlier than that of the Roman conquest. The plate, representing a plan of a Greek Theatre, which is given with this Work, is taken from the edition of Vitruvius, published by Mr. Wilkins: see pl. viii.

According to Suidas, a Theatre of wood was erected at Athens about 498 years before Christ, for the purpose of exhibiting a Drama of Pratinus, and the timbers gave way during the representation. After this, the Athenians erected one of stone, which was finished by Lycurgus, the Orator, about 170 years afterward. This was probably that called the Theatre of Bacchus, the ruins of which are yet to be seen at the South-Western angle of the Acropolis. It is formed by a semicircular excavation of the rock, from the inclining sides of which the seats of the spectators were cut, which, consequently, were supported by the rock itself. A semicircular wall is carried round the upper part of the excavation, and is strengthened by buttresses on the exterior of the Theatre. This wall, which probably formed the back of the colonnade above the seats, is 248 feet in diameter, and 7.8 feet thick, and has rectangular recesses made in it, with vaulted tops. The lower part of the wall of the scena remains in the gorge of the excavation, with part of the staircases at each extremity. This contains some semicircular-headed arches; but both it and the semicircular wall are of later date than the original Theatre, and probably were the work of Herodes Atticus.

The Odeon of Pericles.

The Odeon was a building similar to a Theatre, and intended for the exhibition of Musical performances. Pausanias describes one, which was erected at Athens by Pericles; and the authors of the *Antiquities* of that city suppose that a semicircular excavation in the rock of the Acropolis, below the South-Eastern angle, is the place in which it stood. It must have resembled a Theatre in form, but probably it had no scena, and in the gorge of the building might be a portico or colonnade. Pausanias says the roof was like the tent of Xerxes, which may imply that it was of a conical form. The colonnade was adorned with the prows and sterns, and the timbers of the roof were formed of the masts of the vessels which had been taken from the Persians.

Remains of Greek Theatres in Europe.

In the Supplement to Stuart's *Athens* is given the present state of the few Greek Theatres the destruction of which is not so complete as to prevent any trace of their plan from being discovered. Of those situated in Europe, besides the Theatre of Bacchus beforementioned, we select the following. At Cheronea are the remains of some, the seats of which appear to have been partly cut in the rock, and in which the diazomata are visible. In one at Argos, the lower range of seats coincides with the circumference of the semicircle, but from the appearance of the ground, it is probable that the two upper ranges were flanked by two walls perpendicular to the scena, and touching the back of the diazomatæ above the first range. Two flights of steps are observable, considerably distant from each other, for the purpose of ascending from the lower to the upper ranges of seats; and there were, probably, two others close to the external walls. On the banks of the Alpheus, at Megalopolis, has been a Theatre, which was erected on one side of an artificial mound.

Ruins of several Theatres are still to be seen in various parts of Asia Minor, and those which are in the best state of preservation are at Stratonicea, Miletus, and Laodicea; representations of which are given in the IId Volume of the *Ionian Antiquities.* In the walls are several semicircular-headed arches, formed by voussoirs, but not the smallest information can be obtained of the date of their construction; and, no doubt, they were erected at the time during which the Romans had possession of that part of the World. In one of the Theatres at Scythopolis, in Syria, Mr. Bankes has discovered a complete example of the echeic chambers under the seats, with a gallery of communication, affording access to each chamber, for the purpose of arranging and modulating the vases.

The Choragic Monument of Lysicrates.

When an individual among the Greeks gave a theatrical or musical entertainment, in which the performers contended with each other for the prize of superior skill, it seems to have been customary to erect a monument in honour of those who gained the victory. The person who gave the entertainment was called Choragus, and the edifice was called a Choragic Monument. The most splendid of these is that which was erected by Lysicrates, about 330 years before Christ, and vulgarly known as the Lantern of Demosthenes. It has a square basement, or pedestal, 12.654 feet high, and each side of which is 9.541 feet long; above this are three circular steps, which support a cylindrical building, 7 feet diameter on the exterior, and 11.25 feet high; this consists of six pieces of marble in the form of portions of a cylinder, cut by planes passing through the axis, and placed together on the pedestal, so as to form an entire cylinder with its axis in a vertical position; but, at each of the six places of junction, a column is introduced in such a way that half of it appears to project beyond the face of the cylindrical wall. This wall is quite plain to within 1.6 feet of the top, where there is sculptured a row of tripods surrounding the building. The columns are of the same height as the cylinder, *viz.* 11.25 feet, including the bases and capitals, and that height is equal to 9.64 diameters.

The columns may be said to be of the Corinthian Order; their shafts are fluted, and the longitudinal fillets that separate the channels, end at top in points of leaves. The base of each column consists of two tori with a scotia between them, and is connected with the pedestal by a congé, or inverted cavetto; the upper torus is in the form of an inverted echinus. The capital is separated from the shaft by a groove surrounding the column, and consists of elegant foliage, disposed about a cylindrical block, which seems to be a continuation of the shaft of the column; a small row of plain leaves, resembling those of the lotus, surrounds it at bottom, and above these is a taller row, composed of clusters of leaves resembling those of the nettle. From the middle leaf in front rise two stems, each of which afterwards divides into two others; of these one pair diverges to the right and left, and curls under the angles of the abacus, the other forms double volutes in front of the capital. The groove which separates the shaft from the capital of the column, seems to leave the lower course of foliage unsupported, and gives the column an unfinished appearance; but if, as is probable, the groove was intended to contain a metallic moulding or row of ornaments encircling the column, that objection is removed: we may observe, however, that though the column is, undoubtedly, in itself, highly elegant, yet the cutting of the capitals by the wall of the building must have always produced a disagreeable effect when the columns were viewed in flank.

The architrave is divided horizontally into three faciæ, and the frize is sculptured with figures representing the story of Bacchus and the Tyrrhenian pirates; in the cornice is a row of dentels resting upon the frize, and the entablature is crowned with a row of plain knobs instead of a cymatium. This kind of ornament above the cornice seems to have been very common in the ancient Temples, if we may judge from the many medals on which it is represented, though scarcely any example of it occurs, except in this building.

The frize and architrave are each formed of one block of marble, cut in the form of a ring; these are crowned by the roof, which is a solid piece of marble, approaching to a conical form on the exterior, and the interior is excavated in the form of a segment of a sphere. The whole roof, or *tholus*, rests upon the cylindrical wall, like that of the Temple of the Winds; the exterior is sculptured to represent a thatch, or covering of laurel leaves, and from the centre rises a tall flower, on which formerly stood a tripod. The tops of the leaves of the tholus approach nearer to a horizontal plane toward the top than they do toward the foot, which gives to the external surface the appearance of a curve of contrary flexure. There is no entrance to the building, nor is there any aperture to give light to the interior. See pl. vi. fig. 6.

Next to the Theatrical buildings of the Greeks it will be proper to show the disposition of the edifices which served for the public promenades and Baths of the citizens; for the Schools of Philosophers; and those in which instructions in gymnastic exercises were given, and the public combats of the athletæ were held. These *Palæstræ* and *Gymnasia* were essential to every Grecian city, for the small States of that Country being perpetually at war with each other, and their towns frequently in danger of a siege, such public institutions enabled the young people to study the Arts, and to practise the exercises which were to qualify them for the defence of the community to which they belonged. Little more of them is now to be known than what may be obtained from a general description given by Vitruvius, (v. 11.) which we have already extracted in our *Miscellaneous Division*, under GYMNASIUM, and which need not, therefore, be repeated here.

At Epidaurus, traces may be seen of a vast system of edifices, containing Temples, Baths, Xysti, and Theatres for the accommodation of persons visiting the Temple of Æsculapius for the recovery of their health. Similar edifices exist in ruins at Ephesus, Laodicea, Alexandria, Troas, and at many other places in Asia; and at Præneste, in Italy.

A very ancient edifice, probably a Palæstra, formerly existed at Thoricus, on the South-Eastern coast of Attica. It was of a rectangular form, 104.67 feet long, and 48 feet wide, and consisted of a space enclosed by columns, but without walls; the columns stood on a general basement formed in steps on each side, and were of the Doric Order, fluted at top and bottom only, but no part of the entablature remains. The number of columns in front of the building was seven, from which it is inferred that the building could not have been a Temple; since then there must have been a column opposite the doorway, contrary to the practice of the Ancients, and to every notion of convenience; the number in flank was fourteen. The height of the columns is 17.441 feet, and the lower diameter 3.317 feet.

In the Island of Delos also appears to have been a Palæstra, which, from the name of Philip of Macedon inscribed on the architrave, was probably erected in the time of that Monarch, though its form and the occasion of its erection are both unknown. The columns are of the Doric Order, and their style is lighter than that of any other known example of the Order. The height of the column is 19.305 feet, and the lower diameter is 2.958 feet; consequently, the height is equal to 6.5 times the diameter, and the height of the entablature is 4.912 feet, or $\frac{1}{3.9}$ of that of the column.

The face of the architrave is in a vertical plane, which, if produced, would fall about the middle of the length of the column in front; the faces of the metopes are in the same plane, and those of the triglyphs project about two inches in front, as is the case in the frize of the Temple of Apollo, in the same Island. The echinus in the capital has nearly the form of an inverted frustum of a cone.

This must be considered as the latest example of what may be called the Grecian Doric; that Order, soon after this time, ceased to be employed in Greece, and instead of it was substituted the Corinthian.

The remains of a building coming under the denomination of a Palæstra are still to be seen at Athens. The authors of the *Antiquities of Athens* call it the Stoa, and they suppose it to be that which Pausanias calls Poikile, and from which the followers of Zeno had the name of Stoics; but from the indications of a Roman style observed in it, the conductors of the recent edition of that Work, think it may have been one of the buildings erected by Hadrian.

It is a rectangular enclosure, 376 feet long and 252 feet broad; and in the middle of one of the shorter sides is an entrance gate, elevated on a stereobata, to the top of which there is an ascent by six steps. This portico, which is 34 feet long and 21 feet broad, has four Corinthian columns in front, and is covered by a pediment roof. The whole extent of this side of the enclosure is also ornamented with Corinthian columns detached from the wall, and standing on pedestals as high as the top of the stereobata; and the entablature of the wall is broken vertically, so as to project from the wall over each column. The two lateral walls of the quadrangle are extended about 16 feet beyond the line of that front, and each extremity is ornamented with a Corinthian pilaster. About the middle of each of the lateral walls was formed a projection towards the exterior, of about the same dimensions as the portico beforementioned, and, like it, intended probably for an entrance; and nearly midway between each of these projections and the two end walls of the enclosure, was formed a semicircular recess, 33 feet in diameter, which perhaps was intended as an exedra, or retired place for conversation.

There are traces, quite round the interior of the quadrangle, of a peristyle or colonnade, consisting of a double row of columns at about 23 feet from the walls; and near the middle of the quadrangle are some old foundations, but it is impossible to determine to what they have belonged.

Peristyle at Pæstum.

At Pæstum, in Italy, are the remains of a peristyle which, as has been said, was formerly considered to be part of a pseudodipteral Temple, but the destination of which is now thought to have been very different. The columns stood upon a rectangular basement, 177 feet long and 75 feet wide, with each side formed in steps like those surrounding a Temple. In front were nine Doric columns, a circumstance which, one would think, might have led to a suspicion that the building could not have been a Temple, since one of the columns must have been opposite the entrance. The peristyle has eighteen columns in each flank, and there is a row of columns along the middle of the interior, and parallel to the flanks, probably for the support of a general roof, which, as there was no cella, would require such support from the impossibility of getting materials long enough to extend across the breadth of the edifice. A work thus constructed may, with great probability, be supposed to have been intended for the performance of gymnastic exercises, for the delivery of Philosophical lectures, or it may have served as a market-place.

The height of the columns is 20.965 feet, and the diameter at bottom is 4.709 feet; but the sides of the shaft are remarkably curved; at one-third of the height the diminution is $\frac{1}{20}$ of the lower diameter; at two-thirds the diminution is $\frac{1}{12}$, and at the top of the shaft is $\frac{1}{8.04}$. Where the antæ of a Temple would be, there are here two pilasters which present some peculiarities. They are 20 feet high, including the capital, the height of which is 3 feet; the breadths at top and bottom are nearly equal to the upper and lower diameters of the columns, and the sides are curved in a similar manner. A plain fillet separates the shaft from the capital, which has the form of a cavetto, projecting at top and resembling that which crowns Egyptian buildings; it is covered by a square abacus, and has a small ornament suspended from each angle.

The peristyle was crowned by an entablature, of which the face of the architrave, if produced, would fall a little within the foot of the column; and a large moulding, now destroyed, separated this member from the frize. The exterior of the frize is in a vertical plane, which falls a little within the hypotrachelion, and there are no triglyphs. The cornice is entirely lost.

It is right to observe here, that, in modern Architecture, the name of *Portico* is given only to the columns and roof placed before a doorway; but the Romans applied the term, generally, to any system of columns supporting a roof. Thus the colonnade surrounding a building on the exterior, or any court in the interior, was called, indifferently, peristyle or porticus.

CHAPTER VII.

The Principles of Grecian Architecture.

The reason of adopting proportions in the formation of Temples.

It seems to have been the intention of the ancient Architects that the lengths, breadths, and heights of Temples, as well as the dimensions of all their members, should constantly bear certain proportions to each other; so that all such buildings might be constructed according to a system founded on the established relations between the parts of which they were composed. This is what is signified by Vitruvius, in the Ist Chapter of the IIId Book; and the reason given by this writer for adopting such a system of proportions in sacred edifices is, that the different parts of the human figure bear also certain proportions to each other, which are nearly constant; and he means to infer that because Nature has thought fit to use proportions in the formation of her noblest creature, proportions should also be used in those edifices which, being appropriated to the worship of the Deity, ought to be of the most perfect construction.

The relations between the several members of the Grecian Orders will be presently exhibited from the existing examples of those Orders; we purpose here only to show what relations, if any, subsisted in the general elements of the Temples themselves.

The proportion between the length and breadth of Temples.

In the IVth Chapter of the IVth Book, Vitruvius, speaking of rectangular Temples surrounded by columns, states that the length of the Temple should be double its breadth; and, as he mentions afterward the proportions of the cella and pronaos, his meaning probably is, that that proportion should subsist between the two sides of a parallelogram which pass through the centres of the surrounding columns, or which circumscribe the bottoms of all their shafts.

But though there is an approximation to this proportion in all the Greek examples, it cannot be said that it holds good precisely in any one of them. In the Temple of Jupiter, at Selinus, the length is to the breadth in the ratio of 2.05 to 1; in the Temple of Theseus, these terms are to one another as 2.3 to 1; and from a mean of the six best examples of the Doric Order in Greece and Sicily, the proportion between the length and breadth is as 2.21 to 1.

Distribution of the columns in front and flank.

In order to give to the flank and front of a Temple the proportions he requires, measuring on lines passing through the centres of the columns of the peristyle, Vitruvius directs that the number of intercolumniations on each flank should be double the number on each face; which, if all the diameters of the columns and the intervals between them were respectively equal, would be quite correct; but in the Greek Temples these two conditions do not take place; and as the central intercolumniation is made wider than the others, in order to afford sufficient space for persons who are to enter the door, while those of the flanks are nearly all equal; it follows, that by this rule the length of the Temple would be found less than twice its breadth. In order, perhaps, to approach nearer to the required ratio, the Temples of Jupiter, at Selinus and at Ægina, have the number of columns in flank exactly double the number in front, and, in fact, in those examples, the length is to the breadth as 2.1 to 1, which is nearly the proportion prescribed by Vitruvius.

But in the later examples of the Doric Order, the Greek Architects seem to have intended to increase the ratio of the length to the breadth, by adopting a rule nearly as simple as that of Vitruvius; for we find in the Temples of Theseus and of Minerva Parthenon, at Athens, and in those of Juno Lucina and of Concord, at Agrigentum, the number of intercolumniations in flank is double the number of columns in front, or which is the same thing, the number of columns in flank is one more than double the number in front; and in these examples, the lengths of the Temples are to their breadths nearly in the ratio of 2.3 to 1. The proportion is still higher in the two smaller Temples at Selinus, and in that at Ægesta, which have the number of columns in flank greater, by two, than double the number in front. Perhaps the Greeks were led into this deviation from the simplicity of the first rule, by some idea of the beautiful appearance afforded by a long line of flank columns, when viewed by an eye situated near one extremity of the building.

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We should be cautious of adopting, too literally, the opinion often asserted of the perfection of that system of proportions which prevails in the Grecian Architecture. It has been alleged that the magnitude of any one member being given, the form of the whole building, and the distribution of all its parts were determined from it by invariable rules; but this must be understood with some limitation, for the whole practice of the Greeks shows that, in their Architectural works, they used their discretion, and indulged in considerable liberty. It may, however, be safely affirmed, that when a Greek Temple of any given Order was to be built, it was only necessary to decide upon three arbitrary points; *viz.* the diameter of the column, the number of columns in front, and the species of intercolumniation; then every part of the edifice might be determined by established proportions, with a few modifications depending upon local or other circumstances.

Vitruvius seems to consider that a particular number of columns was necessary in front of each of the different species of Temples; *viz.* six for peripteral, eight for pseudodipteral, and ten for hypæthral Temples; but this rule has not been adhered to in practice; the latter kind of Temples, for example, have sometimes ten, sometimes eight, and, occasionally, only six columns in front. On contemplating the forms of the Greek Temples, we cannot avoid perceiving that they possess a great and noble simplicity of character; every member appears to have its use, and the horizontal lines of the stereobata and entablature, being unbroken, permit the length and breadth of the edifice to be appreciated at once by the eye.

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The Orders, or systems of Architecture, are distinguished by the forms of the columns, and of the entablature above them; and from the account that has been given of the most celebrated buildings of Greece, we shall be able to draw some conclusions respecting the general features of the Orders employed in that Country; and obtain a knowledge, not of the proportions which are to be invariably adhered to in the construction of an Order, but of those from which a deviation may be permitted, only within certain limits, which are authorized by these examples.

The following Table, formed from the Works referred to in the preceding account, exhibits, in one view, the dimensions, in English feet, of the columns and entablatures belonging to the principal examples of the Grecian Doric Order, and will be useful in enabling us to ascertain the characteristic proportions of that Order

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in particular. The height of the architrave is measured to the top of the fillet between it and the frize; the height of the frize is measured to the top of the capital of the triglyph, and the height of the cornice to the top of the corona; the height of the epitithedas is not included.

Names of Edifices.	Height of shaft.	Height of capital.	Bottom diam.	Upper diam.	Height of architr.	Height of frize.	Height of cornice.	Height of entablat.
Temple at Corinth..................	21.335	2.365	5.83	4.34	4.722	....	....	....
Temple of Jupiter Panhellenius, at Ægina	14.374	1.422	2.927	2.172	2.5	2.5	....	....
Temple of Jupiter, at Selinus..........	43.791	4.792	10.625	6.3	9.18	8.	4.58	21.76
Temple at Ægesta....................	26.788	3.308	6.6	4.917	5.475	5.76	3.532	14.767
Temple of Minerva, at Syracuse........	25.459	3.208	6.503	5.004	....	....	....	....
Temple of Juno, at Agrigentum........	18.259	2.573	4.508	3.406	4.146	3.354	....	...
Temple of Concord, at Agrigentum....	19.19	2.321	4.642	3.562	3.615	3.58	1.937	9.132
Hypæthral Temple, at Pæstum........	27.106	2.846	7.06	4.817	4.92	4.74	2.5	12.16
Hexastyle Temple, at Pæstum.........	17.958	2.396	4.244	3.043	3.219	3.167	1.75	8.136
Portico at Pæstum....................	18.96	2.	4.709	3.167	....	....	....	....
Portico at Thoricus..................	16.079	1.362	3.317	2.517	....	....	....	....
Temple of Theseus, at Athens.........	17.075	1.66	3.304	2.552	2.742	3.096	1.008	6.846
Temple of Minerva Parthenon, at Athens	33.636	2.267	6.15	4.812	4.425	4.371	2.395	11.192
Temple of Apollo, at Delos...........	17.004	1.717	3.092	2.333	2.577	2.242	1.056	5.875
Portico of Philip....................	18.3	1.005	2.958	2.441	1.891	2.158	0.863	4.912
Portico in the Agora, at Athens.......	24.581	1.625	4.337	3.383	3.183	3.467	1.162	7.812

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In all the examples of the Grecian Doric Order that have been given, we may observe that the style is extremely heavy. The height of the columns, including the capitals, is, except in one or two instances, only from four times to five and a half times the diameter at bottom. The capital is equal in height to about half the lower diameter, and the height of the entablature, not including the epitithedas, is about one-third of the height of the column, or about one-fourth of the whole height of the Order; that is, of the column and entablature together: the heights of the architrave and frize are nearly equal to each other, and that of the cornice is about half the height of either of the others, or one-fifth of the whole entablature. The members of the whole Order are large, and are composed of few parts, as if it was intended that the buildings should be seen to advantage from a considerable distance, where the effect of small ornaments would have been lost.

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The more particular characters of this Order may be expressed as follows: the columns have no bases, and this rule may be considered as without exception, if we omit two or three of the examples in Italy and Sicily: perhaps, the edifice, being raised on a platform the sides of which were formed in steps, these served as a general base for the whole system of columns, and a particular base for each was thought unnecessary. The shafts are cut longitudinally, by twenty *striæ*, or channels, every two of which, in almost every case, unite in an edge; the transverse section of a channel is frequently circular, but, in some cases, as in the Temple of Apollo, and in the Portico of Philip, they are elliptical. This channelling, however, was not universally adopted, for in several examples which have been described, the channels exist only very near the capital and at the foot of the column, the rest of the shaft being plain. The abacus is, in every example, of a square form, with vertical sides; the echinus, though beautifully curved in the vertical direction, is nearly an inverted frustum of a cone, but rounded abruptly at the upper extremity; the lower extremity is surrounded by three or four annulets projecting from it, having their upper and lower surfaces either horizontal or inclined upward from their outer extremities, and having their exterior faces either vertical or parallel to a tangent drawn to the echinus from its foot. At a short distance below the echinus is cut one or more horizontal grooves, generally rectangular, round the column, making a separation between the hypotrachelion and the rest of the shaft. By a mean of several examples, the projection of the face of the abacus, from the axis of the column, is equal to 0.565 of a diameter of the column.

A remarkable circumstance in some of the Grecian Temples in Sicily and Italy deserves to be mentioned; *viz.* that the diameter of the column at the hypotrachelion, is considerably contracted, and the echinus seems to rest on the top of a row of leaves which crowns the shaft. It is difficult to account for this caprice, which can hardly be reconciled with any principle of good taste, as it destroys that appearance of strength which should be the inseparable quality of a column.

Diminution
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shaft.

The shafts of the Grecian columns have been shown to diminish, invariably, from bottom to top; a practice supposed to have been drawn from the law observed by Nature in the formation of the bodies of trees. Now, if columns were to be viewed from an infinite distance, there is no reason why short and tall columns, of one and the same Order, when employed for the support of buildings of similar forms, should not themselves be similar bodies; in which case the upper and lower diameters would always bear a constant ratio to each other, or to the length of the shaft; but on account of the apparent diminution of objects, when elevated above the eye, it is evident that this constant ratio ought not to subsist if the apparent forms of all columns, of the same Order, are to be similar when the eye is situated at the same distance from a lofty as from a short column, and in, or near a horizontal plane passing through its foot; and it is also evident, that the difference of the upper and lower diameters should be less as the height of the column increases, on account of the greater diminution which the upper part of the taller object will experience. It is for this reason Vitruvius recommends that the upper diameter, which he makes equal to five-sixths of the lower, when the column is not more than fifteen feet high, should be seven-eighths of the lower, when the column is fifty feet high. In these extreme cases, the differences of the upper and lower diameters are one-sixth and one-eighth of the latter respectively; and if we assume the mean height of the shaft of a Doric column to be 4.5 diameters, the differences of the semi-diameters at top and bottom will be $\frac{1}{54}$ and $\frac{1}{72}$ of the lengths of the shafts respectively

But, whatever propriety there may be in these rules, and Vitruvius professes to follow those given by the Grecian Architects, it does not appear that, in practice, the latter paid much attention to them; for, of sixteen examples of the Grecian Doric Order which we have compared together, we find that the difference between the upper and lower diameters of the shaft varies from one-fifth to one-third of the lower diameter, and the mean of all was one-fourth nearly. But as this mode of expressing the diminution does not indicate, what seems to be the most important point, *viz.* the obliquity of the side of the shaft to the axis, supposing the former to be rectilinear, which is nearly the case; we have compared the excess of the lower above the upper semidiameter with the length of the shaft, and we have found that, when the columns were between fifteen and twenty feet high, the diminutions were from $\frac{1}{38}$ to $\frac{1}{70}$ of the height of the shaft, and the mean was $\frac{1}{50.8}$; when they were between twenty and thirty feet high, the diminutions were from $\frac{1}{25}$ to $\frac{1}{50}$, and the mean was $\frac{1}{37}$; and, when between thirty and fifty feet high, (leaving out one example in which the diminution was only $\frac{1}{16.5}$.) the diminutions were from $\frac{1}{34}$ to $\frac{1}{65}$, and the mean was $\frac{1}{48.6}$; from all which it appears, that nearly the same diminution was given to the highest as to the lowest columns; of the intermediate columns, two, whose heights were equal, differed in their diminutions as much as $\frac{1}{22.6}$ and $\frac{1}{38.8}$. Either, then, no Optical principle was adhered to in giving the diminutions, or they must have been regulated by the situations of points of sight which we have it not now in our power to ascertain. The variation of the diminution on account of the point of sight being very near the column is, however, of little consequence; for as is observed by Sir William Chambers, the nearness of the object renders the image thereof indistinct, and, consequently, any small alteration imperceptible.

Form of the shaft.

It has been said that the outline of a section of the shaft, passing through the axis, is a curve concave towards the axis. This form is alluded to by Vitruvius when he describes the column as having a swell, or entasis, in some part of its length. His Commentators, however, are not agreed whether he means that the middle part of the shaft should be greater in diameter than the bottom, or whether the section should diminish from bottom to top, so that each side may be in a curvilinear direction, presenting its concavity to the axis, which would give the appearance of a swell. Palladio felicitates himself upon the former idea, but the measurements of all the ancient examples have confirmed the general opinion, which is in favour of the latter. The only argument, if it may be called one, which could be offered in support of the other is, that a timber column compressed by a weight, acting in the direction of its length, would swell out near the middle before breaking, and it is conceivable that some observation of this fact may have suggested the idea of giving to columns a similar swell, to men who were bent upon copying Nature even in her deformities; but, to give such an appearance as an ornament is, evidently, one of the greatest abuses of principle into which a depraved taste can fall, and, except something like it which occurs in a few of the Egyptian examples, it was reserved for an Age later than that of the Greeks to incur the reproach of such deviations from propriety.

The curvature of the outline of the shaft is supposed to have been given from some refined perception which the Greeks might have had on the subject of the apparent diminution of objects on account of their height above the eye; and Vitruvius seems to think that it was intended to correct that apparent diminution in some way or other. The Roman author does not explain himself upon this subject, but modern artists, who entertain the same opinion, found it on the circumstance, that the sides of the shafts of columns which are, accurately, either cylindrical or conical, from some cause with which we are not well acquainted, assume, to the eye, the form of curves whose convexity is toward the axis; this appearance conveying an idea of weakness, the Ancients might have attempted to remedy it by giving them a convex form on the exterior, in order to make them appear conical. If we suppose that the Greeks had this notion, it must be owned that they did not always confine themselves to the mere correction of the concave figure; for they made the shafts of some of their columns, as those in the Temples at Pæstum, to curve so much as to appear very sensibly convex; and this inclines us to favour another opinion, which is, that the curvature of the profile was merely an imitation of the forms of certain trees.

The apparent concavity of the conical shaft of a column is a fact of general observation, but it is at variance with the form determined by the rules of perspective, and no satisfactory reason has yet been assigned for it. The opinion at present received is, that it may be the result of an erroneous judgment which the mind makes of relative magnitude, when bodies of different sizes are presented, at the same time, to the eye: thus the entablature and stylobata of a building produce perceptions of magnitude which cause the smaller object between them, *viz.* the shaft of the column, to appear less than it is in reality. This explanation is liable to some objections, and we venture to suggest the following, which has the advantage of being less Metaphysical. When we direct the axis of the eye to the middle of a tall column, the organ accommodates itself to the distance of that part of the object in order to obtain distinctness of vision, and then the oblique pencils of light from the upper and lower parts of the column, do not so accurately converge on the retina; hence arises a certain degree of obscurity, which always produces a perception of greater magnitude than would be produced by the same object if seen more distinctly. The same explanation may serve to account for the well-known fact, that the top of an undiminished pilaster appears so much broader than the body of its shaft; to which, in this case, may be added some prejudice in the mind, caused by our more frequently contemplating other objects, as trees, which taper towards their upper extremities.

Appar diamet colum the ang buildi

Vitruvius, in the IId Chapter of the IIId Book, considers that the diameters of columns at the angles of buildings appear smaller than those of the intermediate columns in the peristyle, on account, as he says, of their being more surrounded by the air; that is, probably, on account of the columns, in one case, being seen against a bright ground, and, in the other case, against the walls of the building, which being behind the colonnade are generally in shadow: and, in order to compensate for this Optical diminution, he recommends the former columns to be made thicker than the latter by $\frac{1}{50}$ of a diameter. This rule is, no doubt, drawn from the general practice of the Greek artists, who in the Temples of Theseus and in the Parthenon have made the columns at the angles to exceed in diameter the intermediate columns by $\frac{1}{28}$ and $\frac{1}{44}$ of a diameter respectively. Vitruvius also directs that the columns between the antæ before the pronaos should be less in diameter than those of the peristyle, or colonnade surrounding the Temple, for a similar reason. But there is a difference of opinion among modern artists concerning the apparent magnitudes of columns which are seen against a bright ground; to some eyes they appear larger than those seen against a dark ground, though the former is considered as the more general case, and these opposite deceptions admit of explanation from Optical principles. Both opinions may be confirmed by the practice of the Ancients, since, though it was generally the case, they did not always make the angular columns thicker than the others; and in the Temple of Minerva at Syracuse, the columns of the pronaos, which must have been seen against a dark ground, are thicker than those which surround the Temple, contrary to the precept of Vitruvius, and to what we observe in many other buildings.

Other reasons may be offered to justify these rules of Vitruvius; first the angular columns should be thicker than the others in order to give them more strength, where greater strength is required; secondly, the columns between the antæ should be more slender than those of the peristyle, not only because they have less weight to support, but also, because they will thereby have a greater apparent distance in perspective. It may be observed here that these interior columns were, by the Ancients, placed not exactly opposite those of that part of the peristyle which was in front, in order that they might not be entirely concealed by the latter.

The architrave is plain, and its face is situated nearly vertically over the circumference of the foot of the column, though some examples exist in which this is not the case; in the Portico of Philip, the face of the architrave, if produced downward, would cut the front of the shaft of the column about the middle of its height; and, in the Temple at Pæstum, it stands over the circumference of the top of the shaft. Above the facia of the architrave is a plain rectangular fillet which serves to mark the separation of this member from the frize.

It seems to have been the intention of the Greek artists to consider the exterior faces of the triglyphs as coinciding with the general face of the frize, and to consider the metopes as sunk within it; for in the best examples of the Order, such as the Temples of Theseus and of Minerva, at Athens, the faces of the triglyphs are in a vertical plane coinciding with that of the architrave nearly, and the metopes are in a plane parallel to that of the architrave, and distant from it, towards the axis, about one-twentieth of the diameter of the column. There are some exceptions, however, to this disposition; for in the Temples at Selinus and at Ægesta, in Sicily, and of Apollo at Delos, the faces of the metopes are in the same vertical plane as that of the architrave, and those of the triglyphs project before it. The breadth of the triglyph is nearly an arithmetical mean between half the upper and half the lower diameter of the column, and is divided into three vertical parts, each of which, called by the Greeks *meros*, is formed into three sides, of which one is parallel to the front, and the others make angles with it equal to those between the sides of a regular octagon, so that there are left two channels between the three parts; the middle of a triglyph is made to correspond with the axis of each column, but the exterior edges of the two extreme triglyphs are placed close to the extremity of the frize. This may be considered as universal in the Grecian Doric Order; the only exception, perhaps, being in the hexastyle Temple at Pæstum, where the centres of the extreme triglyphs correspond with the axis of the columns at the angles.

The metopes are nearly equal in breadth to the height of the frize; consequently they are nearly of a square form, though the practice is not universal; and this equality of breadth, together with the disposition just mentioned, of the extreme triglyphs, is the cause why the interval of the two columns nearest to each angle of the building is always less than that between any two of the other columns. On the flanks of the building, as well as on the front, a triglyph is placed close to the angle, so that, at each angle, two triglyphs come together; a circumstance which is at variance with the idea that the triglyphs represent the ends of beams placed across the building, since two such beams could not have their extremities visible on both faces, as has been before observed.

Distribution of the triglyphs, &c.

An opinion has been entertained that the Greek artists aimed at perfect regularity in the dimensions and disposition of the triglyphs and metopes, and, consequently, in the magnitude of the intercolumniations, which were limited by the necessity of having a triglyph to correspond with each column, and either one or two over each interval between the columns. It has been supposed that those persons considered it indispensable that the breadth of the triglyphs should be invariably equal to half a diameter of the column, and that the metopes should be perfect squares. In consequence of this opinion, no small embarrassment has been felt in distributing the several parts of an edifice which was to be constructed according to this Order; and the formation of a Doric design, in which all the conditions shall be fulfilled, has been considered as a Mathematical problem of great intricacy. But the works of the Greek Architects do not indicate that any such perfect regularity was attained in practice. The triglyph at the angle is frequently made wider than the others; and, in the most superb building of antiquity, the Parthenon itself, all the metopes are not complete squares; the three of them nearest to each extremity of the front having greater breadth than height, in order, no doubt, to gain a small increase in the corresponding intercolumniations, for the convenience of persons passing between the columns. In some of the ancient Grecian Temples, it appears that the spaces between the triglyphs remained unclosed; in proof of this it has been observed that in the *Iphigenia in Tauris* of Euripides, Pylades proposes to Orestes to enter the Temple through those spaces. These apertures, which must have been in the entablature over the walls of the cella, were, probably, as is observed by Lord Aberdeen, for the purpose of giving light or air to the interior; or it might be that the Temple was left in an unfinished state.

It has been shown that the Doric frize is sometimes ornamented with sculptured figures; and of these the best specimens are, perhaps, found in the Temples of Theseus and of Minerva at Athens. One peculiarity in the design of the Greek sculptured frizes deserves to be noticed, *viz.* that where sitting figures are introduced, the height of them is equal to that of the standing figures, so that, if the former were to rise from their seats, they could not be contained in the frize; this was probably done to avoid leaving unoccupied that part of the frize which would be above the head of the sitting figure. A proof that in sculpture, as well as in Architecture, the Greeks sometimes sacrificed Truth and Nature to the production of a rich effect.

The corona or cornice.

Above the frize is a course of masonry which seems to support the corona, and, on that account, is called the bed-moulding of that member; it is generally divided horizontally into two faciæ, both of which project beyond the faces of the metopes and triglyphs, being broken vertically, at intervals, so as to form such projections; and those parts which are immediately above the triglyphs are called the capitals of those ornaments. The corona, properly so called, which forms the principal member of the cornice, is a course of masonry placed above the bed-moulding; and, from a mean of several examples of this Order, we find that its projection from the axis of the column is equal to 0.882 of a diameter of the column, or 0.426 of a diameter from the face of the frize or of the architrave. The soffit, or under surface of the corona, is generally formed in an inclined plane both on the faces and flanks of the building, the outer extremity being the lowest. The mutules are thin plates applied to the soffit of the corona, both over the triglyphs and over the middle of the metopes; they are of a rectangular form; their length, in the direction of the face of the building, is equal to that of the capital of the triglyph, and their breadth equal to the projection of the corona beyond that capital. From their under surfaces are suspended three rows of conical or cylindrical or sometimes trochoidal guttæ, or drops, each row being parallel to the face of the building and containing six drops. One row of similar drops is attached to the under surface of a block, to which the name of *regula* is given, and which is placed under each triglyph against the face of the architrave.

Over the front and rear faces of the building, a fillet or some small moulding, above the plain face of the horizontal corona, forms the termination of the Order: the inclining sides of the pediment consist each of a plain member similar to the corona with a fillet above, and over this is a large moulding, generally in the form of a cymatium, but sometimes of an echinus, which being the crowning member of the building, has the name of epitithedas. This moulding in some cases, perhaps, returned along both flanks in horizontal directions, and, consequently, formed the summit of the Order on those parts; but, in the Parthenon it only extends a little way on each flank and terminates in a lion's head. Over the cornice of the flank is, in this case, a row of fleurons, at intervals from each other, extending from front to rear of the building.

The fillet, or the curvilinear moulding, at the upper part of the corona, has its under-surface generally excavated so as to form a bird's-beak; this practice was, probably, in some measure intended to prevent the rain from the upper part of the building flowing down upon the part below; but it is, besides, supposed to have been dictated by the wish to produce a great contrast between the light and shade, in preventing any reflected light from falling upon the part in shadow, which, afterward, arriving at the eye, would diminish the obscurity.

Doric pilasters.

With respect to the antæ pilasters, in the Doric Order, we find, from the Greek examples, that, except where the pilasters are placed on the pavement of the Temple, which is higher than that of the peristyle, the pilasters are of the same height as the columns of the peristyle; they are rather less in breadth than the diameters of those columns, and the breadths at top and bottom are equal. Instead of an echinus, similar to those of the capitals of the columns, there are, in some examples, three plain faciæ formed at the top of the pilaster, of which the upper one projects over the shaft about half as much as the abacus of a column projects over the top of its shaft, and its under-surface is, usually, excavated upward so as to form a groove along the face and flanks of the pilaster. In other examples, as in the Athenian Temples, the upper facia is formed in mouldings the sections of which are curvilinear, and the under-surfaces of some of these are also excavated upward so as to give to the mouldings the bird's-beak form. The thickness of the antæ pilasters in flank is about equal to half the diameter of the columns in the same building: greater thickness than this would have made them appear too heavy.

The pilasters being of equal breadth at top and bottom, while the columns diminish in diameter upward, it is evident that if the former were equal in breadth to the lower part of the column, they would appear larger than the columns; and this effect would be increased when the pilasters were viewed obliquely on account of the diagonal breadth being larger than that of the face. These circumstances justify the rule given by Vitruvius, and which the Greek artists have uniformly adhered to; *viz.* to make the breadth of the pilaster rather less than the diameter of the column adjacent to it, for, by so doing, they both appear to the eye of equal magnitude.

Uncerta estimat the anti quity of amples their pr portion

In contemplating the examples that remain of this Order, in Greece and Sicily, we find that its proportions were various in respect, first to the ratio between the height of the column and its diameter; secondly, to the degree of diminution of the shaft; thirdly, to the ratio between the height of the capital and the diameter of the column, and, lastly, to the height of the entablature. Various efforts have been made to determine the degree of antiquity of any example by the proportions of the columns in some or all of these respects; but the only thing certain is, that, in general, the oldest columns are those the heights of which are the least multiples of the diameters of their shafts; the other conditions are too variable to serve for the establishment of a general law.

The practice of embellishing the Grecian Doric Temples by painted ornaments, may be inferred from the description we have given of those on the Parthenon; and we have only to add that this practice seems to have been very general. The traces of the paintings are, now, nearly obliterated, but, from what has been discovered, it is evident that the greatest pains have been taken in executing the outlines of the ornaments, which have been drawn by masterly hands. We cannot, however, avoid contrasting this species of embellishment with that executed in the marble itself; the former has long since vanished, while the latter remains an eternal monument to the talent of the artist.

Genera proport of the cian Io Order.

From the examples that have been given of Temples constructed by the Greeks according to the Ionic Order, we perceive that the essential forms remain nearly the same as those of the Doric Order, but that the difference in the proportions of the column and entablature is considerable. In order to make the comparison with more facility we subjoin a Table similar to that which has been given for the Doric examples. The dimensions are in English feet, and the height of the epitithedas is not included in that of the cornice.

Names of Edifices.	Height of shaft.	Height of capital.	Height of base.	Lower diam.	Upper diam.	Height of architr.	Height of frize.	Height of cornice.	Height of entablat.
Minerva Polias at Athens.....	22.76	1.954	1.108	2.786	2.291	2.354	2.217	0.942	5.513
Erectheus at Athens..........	19.8	1.833	0.921	2.317	1.933	2.084	1.98	0.871	4.935
Temple on the Ilyssus near Athens	12.789	1.014	0.889	1.783	1.517	1.644	1.472	0.484	3.600

By taking a mean of these examples, we find that the height of the columns is 8.95 times the diameter of the lower part of the shaft, which is a much higher ratio than was found to subsist in the Doric Order. A new member is introduced; *viz.* the base of the column, the height of which is about equal to half a diameter; the capital is altered in form from that of the Doric Order, though not in proportion. The mean height of the entablature, not including the epitithedas, is $\frac{1}{44}$ of the height of the column, or $\frac{1}{5}$ of the height of the whole Order. The heights of the architrave and frize are nearly equal to each other, as in the former Order, but that of the cornice is about one-third of either of these, or one-seventh of the whole height of the entablature. From all which it follows that the general effect of this Order is considerably lighter than that of the Doric.

In the Temple of Erectheus, and in that on the Ilyssus, the bases of the columns consist of two tori, of a semicircular form, separated from each other by a scotia, with plain fillets above and below; the lower torus rests immediately upon the pavement, or upon a step which serves as a general plinth for all the columns of the building, and the upper fillet is joined to the shaft by a curve, concave outwards, called the *apophyge.* In the bases of the columns of the Erectheum, the fillet above and below the upper torus projects only as far from the axis of the column as the centre of the curvature of the torus; but, in the Temple on the Ilyssus, the fillet below the upper torus projected as much as the extremity of the curvature of the torus itself. The fillet below the scotia falls vertically over the centre of the lower torus, but its projection is greater in the Temple of Minerva Polias than in that on the Ilyssus, and, on that account, the base of the former possesses greater elegance. In the Temple of Minerva Polias, the thicknesses of the upper torus, the scotia, and the lower torus are, nearly, in the ratios of the numbers 6, 7, and 8 respectively, and the lower torus projects, from the axis of the column, as much more than the upper torus as is about equal to its thickness; while, in the Temple on the Ilyssus, the projection was not above half as much, and, on this account also, perhaps, we may be allowed to prefer the former. Bases, consisting of such members as we have described, are all called Attic, though they seem to have been used, indifferently, both at Athens and in Asia. The bases of the Ionic columns, belonging to the Asiatic Temples, are, in general, far from possessing the elegance of form which characterises those belonging to the Temples of Athens: in the Temples of Minerva Polias, at Priene, and of Apollo Didymæus, at Miletus, the lower part of the base of the column consists of three double astragals, separated from each other by two small scotiæ, and, above these, is a large torus, nearly equal, in height, to all the rest of the base, and seeming to crush the small mouldings below.

In the Greek bases the mouldings sometimes are, and sometimes are not, ornamented with sculpture. In the Temple of Minerva Polias, at Athens, the upper torus is enriched with what is called a guilloche; in the Temple of Erectheus and that on the Ilyssus, it is fluted horizontally: but this latter method, by cutting the profile of the principal moulding into a great number of minute parts, destroys the character of the whole, and is, perhaps, not to be considered as the most happy refinement adopted by that ingenious people.

The shaft.

The diminution of the shaft, or the difference between its upper and lower diameters, is equal to about one-sixth of the latter, or the difference between the upper and lower semidiameters is $\frac{1}{90}$ of the whole length of the shaft, (taking the mean dimensions of the principal columns of this Order in existence.) Consequently, the diminution in the Ionic Order is much less than in the Doric. A section of the shaft, through the axis, has its sides gently curved, and the surface of the shaft is channelled, longitudinally, in twenty-four or thirty flutes, of a semicircular or semielliptical form, and a plain fillet, equal in breadth to about a sixth part of the breadth of a channel, is left between every two channels.

The capital.

In this Order, the capitals are distinguished by volutes, the planes of which are parallel to that face of the building before which they stand, except in the capital on the column at each angle of the building, which has volutes on both the exterior faces of the capital; and, in order to give symmetry to the two sides of each face, the volutes which meet at the exterior angle are formed obliquely to the faces; for this purpose a projection is made diagonally at that angle, of such extent that the horizontal distance of its extremity from the centre of the column, in a plane parallel to the face of the building, is equal to that of the volute at the next angles of the capital. The volutes being formed on each side of this diagonal projection, the two exterior faces of the capitals on the columns at the angles are similar to each other, and to the front of the capitals of the other columns: by this ingenious contrivance, the Greek artists avoided the defect of presenting the profiles of the volutes of the angular columns on the side faces of their buildings. The spiral curves, or balthei, composing the volute, are double or triple; the principal one springs from under each extremity of the face of the abacus, and bends downward, while the others hang in festoons on the face of the capital, between the volutes.

The top of the shaft of the column is, sometimes, surrounded by an echinus, passing behind the volutes, and having its surface sculptured with figures representing oves and darts; below this is an astragal, and the hypotrachelion, between the echinus and astragal, is ornamented with delicate sculpture. Each side face of the volutes presents the appearance of two frusta of irregular cones, joined together in the middle, and surrounded by rings; and the abacus, instead of being prismatic, as in the Doric columns, has each of its four faces moulded in the form of a cymatium.

The entablature.

The architrave is either plain in front, or it is divided into two or more faciæ, of which each projects over the one below it. The frize and corona are either plain or sculptured; and the bands which separate the architrave from the frize, and the latter from the cornice, are formed in mouldings, which, also, are generally adorned with sculpture. In some examples, as in the Temple of Minerva Polias at Priene, there is a row of dentels immediately above the frize, and over these comes the moulding which forms the bed of the corona. In this situation, we must consider the dentels as representing the extremities of the smaller joists, placed above the timbers of the frize, to support the covering of the roof. The soffit of the corona is excavated so as to form an inverted channel, in a direction parallel to the face of the building, and occupying nearly the whole breadth of the soffit; this was, probably, intended to prevent the rain which fell on the roof from running down the entablature. The lower extremity of the face of the corona is in a horizontal plane passing through the foot of the bed-moulding of the cornice; consequently, the latter member is concealed from the view by the projecting corona, except when the spectator is almost close to the building. By a mean of several examples, the projection of the corona is 0.9 of a diameter from the axis of the column, and 0.41 of a diameter from the exterior of the frize. An epitithedas, generally, in the form of a cymatium, finishes the entablature on the inclining sides of the pediment, and, sometimes, it is continued on the horizontal cornices of the flanks of the building.

Ionic pilasters.

The antæ pilasters employed in this Order have capitals which are sometimes similar to those of the columns, but without volutes; in other cases they consist of several mouldings either plain or richly sculptured. Their bases are, also, generally, similar to those of the columns, but a remarkable difference occurs in the bases of the pilasters at the Erectheum; the lower torus, instead of being smooth or cut in concave flutes, is formed into a number of astragal mouldings, like a cluster of reeds placed in a horizontal position. The breadths of the shafts of the Ionic pilasters, like those of the Doric Order, are less than the diameters of the columns, and they have no diminution.

It is said that the earliest specimens of the Ionic Order of columns were not in possession of that which, afterward, became one of its most distinguishing characters; *viz.* the volutes in the capital; and this strengthens the opinion that the Order was, originally, nothing more than an improvement on the Doric, by making its columns more slender than those of the more ancient Order, and by giving them bases. The volutes might, subsequently, have been added, in imitation of the small branches of trees, placed about the capital to decorate the Temple; for these, curling under the angles of the abacus, would easily lead to the idea of a permanent ornament like that in question.

Our knowledge of the Greek Corinthian Order imperfect.

The opinion most generally received among the antiquaries of the present day is, that the capital of the columns of the Corinthian Order is an improvement on some of those which crowned the massive columns of Egypt, and the foliage employed on the latter, certainly, in some cases, resembles that which adorns the former. But, without going so far as Egypt for the origin of this capital, we think we may, with equal propriety, consider it as an extension of the principle exhibited on some of the columns at Pæstum, the capitals of which very much resemble vases placed on the stems, and surrounded by the leaves of plants, and it required but the taste of a sculptor of the best days of Greece, by giving height and delicacy to a Doric member, thus ornamented, to produce the elegant capital which adorns the Corinthian column. However this may be, on account of the small number of examples of this Order remaining in Greece, and the uncertainty we are in, whether these are to be considered as correct specimens of the style adopted in that Country, we think it advisable to postpone the general description of the Order till we can introduce it into our account of the Roman Architecture, of which it forms a distinguished part. The few Greek Corinthian examples which can be referred to, are those of the Tower of the Winds, the Choragic Monument of Lysicrates, and the capital of a pilaster at Eleusis. See plates vi. and vii.

Upper; lower t of colu

The hypæthral Temples of the Greeks generally contained in their interior two tiers or Orders of columns placed one above another; but, of such a disposition the only remaining example, which is sufficiently perfect to allow us to form an opinion of the principles on which it was regulated, is the great Temple at Pæstum. In that edifice the columns of both tiers are of the Doric Order, and similarly proportioned; a plain architrave rests on the abaci of the lower columns, and the upper columns are placed vertically over those below, but the height of the former is equal only to about four-sevenths of the others. We learn from Pausanias that the Temple of Minerva at Tegea, which was built in the XCIVth Olympiad, (about 400 years before Christ,) was adorned interiorly with two rows of Doric columns, surmounted by others of the Corinthian Order; or, as Lord Aberdeen supposes, with Ionic columns below, and Corinthian columns above. Those of the exterior peristyle he supposes to have been of the Doric Order.

Opinio conce the or of Car tides.

Besides the three kinds of columns which have been just described, we find, in that division of the triple Temple at Athens, which was dedicated to Pandrosus, female figures employed for the support of the entablature. These figures are called Caryatides, and it has been a subject of much inquiry how the human figure was first employed for such a purpose. If, as Vitruvius intimates, some Grecian artist had conceived the notion of making the proportions of the Doric and Ionic columns the same as those of the human figure; it is not unreasonable to suppose that it might, also, occur to an artist, either Grecian or Egyptian, to cut the column in the form of a man or woman; the idea of making such figures serve for the support of an entablature would easily originate in what must have been the subject of daily observation, *viz.* the application of human strength to the bearing of burthens. The sculpture might, at first, be rude, and, perhaps, some of the earliest examples were those statues which Pausanias saw in Laconia, consisting of shafts of columns, on which a face was carved for the capital, and feet for the base; but, in the progress of Art, such figures would, at length, be brought to the perfect form exhibited in the female statues first mentioned. But so simple an account of the origin of the practice of placing human figures to serve as capitals was, probably, not agreeable to the taste of Vitruvius, and he has heightened the interest of the subject by relating the following circumstances concerning it.

The inhabitants of Carya, in the Peloponnesus, having joined with the Persians, at the time of the invasion of Greece, the city, after the invaders were driven out of the Country, was taken by a combination of the other Greek States, and the people were either put to the sword or made slaves; to perpetuate their disgrace, these statues were employed in the buildings of Greece, and represented their women in the condition of bearers of burthens. Again, Vitruvius asserts that male figures in the Persian costume were employed, in a similar way, in a Portico erected at Sparta, after the battle of Platea, to solemnize the victory gained by Pausanias, the son of Cleombrotus, over a large army of Persians. Now there is nothing to disprove this latter story, but we must not suppose that male figures were then first employed for the support of an entablature; since we find that in Egypt the same practice existed from a period which, there is every reason to believe, is much more ancient than that of the Persian war in Greece.

With respect to the female figures, the account given by Vitruvius of their origin falls to the ground, as, in an inscription brought from Athens by Dr. Chandler, and containing a description of this Temple, the figures are called *κόραι*, or virgins; whence Lord Aberdeen concludes that they were intended to represent the young ladies employed in the celebration of the Panathenaic Festival, who were selected from the best families of Athens. Mr. Gwilt, in his Paper on the origin of the Caryatides, and in his edition of Sir William Chambers's *Architecture*, shows that they, originally, represented the virgins who celebrated the worship of Diana; this Goddess was, sometimes, called Caryatis, either from *καρύα*, the nut-tree, into which Bacchus transformed Carya, one of the daughters of Dion, King of Laconia, or from the fact mentioned by an old commentator on Statius; *viz.* that some virgins who were celebrating the rites of Diana, being threatened with danger, took refuge under the branches of a nut-tree: the same commentator adds, that a Temple in honour of Diana Caryatis was, afterward, erected on the spot, to commemorate the event.

CHAPTER VIII.

Construction of the Grecian Buildings.

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We know but little of the mechanical disposition of the materials in the Greek buildings; all that we can say on this head being derived from the short account given by Vitruvius in the VIIIth Chapter of the IId Book, and from the information of those travellers who have had opportunities of examining the remains of the edifices we have described.

Different kinds of walls appear to have been constructed by the Greeks; one of these is called by Vitruvius *incertum*, and he says it is the most ancient, but, from the obscurity of his description, there is great doubt concerning its nature; some thinking that the bricks or stones were placed irregularly, without regard to either vertical or horizontal courses; others, and their opinion seems the most probable, that the materials were disposed in horizontal courses, but that care was not taken to make the vertical junction of every two bricks, in each horizontal course, fall between the masses of two bricks in the courses immediately above and below them.

He describes the stone walls of the Greeks as of three different kinds: the first, called *isodomum*, has its horizontal courses of equal thickness; the second, called *pseudisodomum*, has the courses of unequal thickness; and he considers both these kinds of wall as possessing great durability. It does not, however, appear whether the Greeks always used smooth, squared stones in masonry of these denominations, or whether the same names were applied to it when the materials were roughly hewn. The third sort is called *emplectum*, and consists of two thin walls of squared stone at a certain distance from each other, the interval between them being filled with flints or rubble stones: these were disposed carefully, perhaps in horizontal courses, at least so that the vertical joints in any two courses were not coincident; and by this means the whole was united firmly together. The Greeks also placed bond-stones, which they called *diatones*, at intervals, stretching quite through the wall, from one face to the other, and serving to increase the stability of the work. The commentators on Vitruvius are, however, divided in opinion concerning these walls, and some think that the Greek isodomum and pseudisodomum, were, at least in some cases, of the kind just now called emplectum.

The walls built by Epaminondas about the city of Messene still remain in part, and these are particularly worthy of remark, because they afford an ancient example of that mode of building described by Vitruvius under the name of emplectum. The entrance leads to a circular court 63 feet in diameter, in the interior surface of which are two niches of rectangular forms both on the plan and elevation, with projecting sills and cornices. On the side of the court opposite this entrance is an interior one which is divided into three parts by two piers of masonry. The exterior entrance was probably flanked by two square towers, of which the foundations remain; from these proceeded the walls of the city, which were strengthened at intervals by square and semicircular towers; the former about 20 feet in length on each side, and the latter about the same in diameter. The walls are 9 feet 3 inches thick; they consist of two faces of wrought stone connected together at certain distances by transverse courses of the same material, and the interval is filled with rubble. The towers and certain parts of the walls are crowned by battlements, and the former are pierced with loop-holes whose sides diverge towards the interior.

Masonry of the Greek buildings.

The labours of Messrs. Stuart and Revely have shown that the wall enclosing the cella of the Parthenon was formed of horizontal rows of marble blocks, each of which was equal in thickness to the wall itself, and that the junctions in each alternate horizontal course were vertically over each other. And this was, no doubt, the method employed by the Greeks where great durability was aimed at. The same gentlemen describe the construction of the other parts of the Temple as follows, and their account will give a good idea of the practice of that people in executing their finest works. The pavement is composed of square stones, of equal size, and the joints are so neatly fitted as to be scarcely discerned. The columns consist of several single blocks placed one on another, and the height of each block is equal to about two-thirds of a diameter of the column. The architrave rests merely on the capitals of the columns, without any fastening, and consists of three blocks in thickness and one course in height, each block reaching, in length, from the axis of one column to that of the next. The frize is formed of one course in height; the metopes are thin plates of stone fixed against the face of the frize, and the block of stone on which the triglyphs are cut are inserted partly in the frize. The cornice is formed of blocks, each of which is equal, in extent of front, to one mutule and a triglyph.

In executing the steps to their buildings, the Greeks left the exterior surface in the rough, about the upper edge, both on the vertical and on the horizontal faces; this was, no doubt, intended to protect the edge of the step from accident during the progress of the building, and was smoothed off after the work was completed. A similar practice was adopted in other parts of their edifices. On the middle of the vertical face of each stone forming a step, a rectangular projection was also left, in order, perhaps, to serve as a handle for the convenience of bringing it to its position; this was afterwards cut off and the face of the step brought to a smooth surface. The inclining faces of walls were also frequently built in the form of steps, by each course of stone projecting beyond the one above it; this was, no doubt, intended to enable the workmen easily to give to the face of the wall the required slope, by cutting off the angles of the courses. In many unfinished works of the Greeks, we find the steps and walls left in the states we have just described.

The close union of the marble blocks, particularly at the vertical joints, in Greek buildings has been frequently the subject of admiration, and is justly considered as a proof of the care taken by the ancient artificers to ensure the stability of the edifices they raised. In order to accomplish this accurate junction of the blocks with the least labour, each of the faces which were to be placed in contact vertically, had its middle part hollowed out in a square or rectangular form to a small depth, so as to leave a raised margin a few inches broad all round the exterior; the surface of this was highly polished, and consequently the two corresponding margins of the adjoining blocks came closely together, so that often the line of junction on the face of the building is imperceptible. By this practice it is evident that the trouble is saved of polishing the whole of the two contiguous surfaces.

In general the Grecian buildings were erected before the ornaments in sculpture were executed; and it seems that these were always cut out of the solid stone, the surface of which had been previously smoothed; the flutings of the columns were evidently executed in that manner, from the appearance of some of the unfinished buildings; though, in some cases, the flutings may have been formed, roughly, on each block before it was brought to its place; and some persons have thought that the plug in the axis of the column, at the junction of every two blocks, served as a pivot for the adjustment of the flutes during the erection of the column.

It is probable enough that, in the earlier periods of Grecian Architecture, the ornaments on the mouldings were painted, and that it was not till a succeeding time, when considerable progress had been made in the Art, that the ornaments were sculptured in the marble. In proof of this it may be observed that, in the capitals of the Doric columns, oves and palmettes are sometimes represented by painting, but never by sculpture, whereas in the Ionic capitals, which are later works, such ornaments are cut in the mouldings, with different degrees of delicacy in different examples. Oves, indeed, are sculptured on the Doric pilasters, but the execution of these is bad, and seems to indicate that they were among the first examples of the application of sculpture to the mouldings in the Orders.

The Greek mouldings are, in general, elegantly turned even in situations where such delicacy may be supposed scarcely perceptible except to a critical eye; the lower part of the echinus for example, always preserves a gentle curvature though it differs almost insensibly from a portion of a cone. But the greatest care seems to have been taken in forming the bird's-beak moulding, where both the anterior and posterior faces of the projecting part are made beautifully convex, and the latter joins the swelling surface of the lower moulding by a concave turn; thus causing the whole to assume the appearance of a beautifully undulating curvature.

The Ancients have sometimes formed the profiles of their mouldings so that, to an eye situated below them, in some given position, they might appear similar to the regular mouldings which they were intended to represent. And, to obtain a good effect, the projections of even the rectilinear mouldings were, by the rules of Optics, adapted to their elevation above the eye. It was for this reason the faces of the architrave and frize of an Order, were sometimes made to incline forward at the top, that, to an eye below, they might appear vertical. This practice, however, is not general, and in the Parthenon the members incline back pyramidally.

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The upper part of the Temples, except those of the hypæthral kind, was covered by one general roof consisting of two inclined planes, meeting in a horizontal ridge at top, and projecting over the flank walls of the Temple. The lower extremities of the roof were either left so that the rain-water might run off at every point, or else the corona was terminated above by a cymatium which formed one side of a gutter to receive the water from the roof; this water was discharged through apertures terminated by lions' heads. The inclination of the sloping sides of the roof to the horizon, in the Greek examples, varies from eleven to fifteen degrees; a mean of several gives, for the angle of inclination, 12° 40′, and the height of the apex of the pediment above the horizontal cornice is about one-ninth of the whole length of the corona in front.

The centre of an hypæthral Temple not being covered by a roof, it may seem that the building must have presented an unfinished appearance to a spectator viewing it in flank, since a chasm must appear to have existed between the pediment roofs at the extremities of the edifice. To fill up this chasm it has been supposed that the four walls of the cella were carried up vertically, like those of a tower, at least to the height of the ridges of the roof, which might then terminate against the upper parts of the end walls of the cella. The whole building would thus appear complete; but it must be owned that no traces of such a tower has ever been observed.

In the small circular, or polygonal buildings, the roof consisted of one solid stone resting on the walls, as may be seen in the Temple of the Winds, and in the Choragic Monument of Lysicrates, at Athens. The inclining roofs of large buildings were covered with rectangular plates or slabs of marble placed in rows, the lower part of the slabs in one row overlapping the upper part of those in the next lower row; and to prevent the rain from entering at the side joints, which, by the arrangement of the slabs, formed continuous lines parallel to each other, from the ridge to the foot of the sloping side, those joints were covered by pieces of marble, called ἁρμὸι, whose superior surfaces were cut so as to form two inclined planes meeting in a ridge over the joint, and whose inferior sides were grooved to receive the two contiguous edges of the plates, which were made to project a little above their general surface.

An accurate idea of the form and proportions of the doors and windows in Grecian edifices may be obtained from those of the Temple of Minerva Polias at Athens, which afford, perhaps, the only specimens remaining of the style of ornament employed about such apertures in the most finished buildings. The doorway under the tetrastyle portico is of a rectangular form, 16.86 feet high, and 7.5 feet broad, and surrounded, both on the horizontal and vertical architraves, by plain faciæ and curvilinear mouldings, separated from each other by lines of beads. The whole breadth of the architrave is 1.625 feet, and on the exterior faciæ are sculptured elegant pateræ. Above the horizontal architrave is a carved moulding ornamented with oves, and over this, but separated from it by a cavetto, is an elegantly sculptured cymatium, which is supported at the extremities by ornamented consoles, contiguous to the vertical architraves and extending downward to the level of the top of the doorway. Between the half columns which are attached to the wall at the Western extremity of the Temple, and elevated considerably above the pavement, are three windows, each 6.375 feet high, 3.1 feet wide at bottom, and 2.862 feet wide at top. The architraves, at the sides, stand on a plain projecting sill, and each extremity of the horizontal architrave is vertically over the exterior of the foot of the jamb. The whole is surrounded by a moulding, whose exterior fillet projects from the face of the wall, and is broken at right angles about the extremities of the horizontal architrave. See pl. vii. figs. 3 and 4.

This subject may, not improperly, be concluded by a description of the methods of tracing the several mouldings employed in the Grecian Orders; their situations on the column and entablature have been already pointed out.

The outline of a section of a Greek moulding is, in almost every case, a portion of some conic section, and to describe such curves it will be only necessary to fix upon the positions and lengths of their axis, and then to apply the usual geometrical or mechanical rules.

The echinus forming the principal feature of the Doric capital, we begin by considering its profile, which may be either elliptical, parabolical, or hyperbolical. A very elegant elliptical echinus will be traced if we assume the lowest point A, (pl. vii. fig. 8.) to be the extremity of the conjugate axis, and the upper point B, both of which may be supposed to be given, to be one extremity of the transverse; we may then draw B C in any direction at pleasure, or parallel to an assumed line A D, (representing a tangent to the curve,) for the direction of the transverse, and A C, perpendicular to it, for that of the conjugate; the intersection of these lines, at C, will be the centre of the ellipse. From the known equation of the ellipse the curve may then be described, *viz.* by determining the length of as many ordinates as we please, and tracing a curve line through their extremities. Or it may be done by any of the means taught in elementary books. The parabolic or hyperbolic echinus may be determined in a similar manner, by assuming the point B for the vertex, and B C for the direction of the axis; a line from A, perpendicular to B C, and meeting it in C, will be a semiordinate to the curve; which, therefore, from the equation, or, by various other means, can be described.

The large torus moulding in the bases of some of the Ionic or Corinthian columns is sometimes made of a semicircular, sometimes of a semielliptical form, the methods of describing which are known; but, in a few cases, we find it in the form of an inverted echinus; which, therefore, may be traced as above.

The scotia, or excavation between two tori in the base of a column, if we consider it as elliptical, may be traced in the following manner. Join A, B, (pl. vii. fig. 9.) for a diameter, bisect it in C, and through C draw C D perpendicular to the axis of the column and equal to the given depth of the excavation; C D will then be a semiconjugate diameter, and the equation of the curve will give the values of the ordinates, by which it may be drawn.

For a cymatium; the given points A and B may be joined, (pl. vii. fig. 10.) and the line A B bisected in C; the vertical line D C E may then be drawn through C, and quadrants of ellipses formed as in the figure, C D and C E being each equal to the semitransverse axis, and A D, E B, each, equal to the semiconjugate.

It has been observed by Mr. Nicholson that the volutes in the capitals of the Grecian Ionic columns resemble that curve which is called a logarithmic spiral; and, in fact, from the best admeasurements that have been obtained, of some of those volutes, particularly those of the Temple on the Ilyssus, and of the Erectheum, they appear to differ so little from that species of curve, that we may safely consider them as such; and, in describing them, we may employ the rules usually given by Geometricians for that purpose; that is, we may determine a number of points through which the curve is to pass, and then trace it, by hand, through them.

A property of the logarithmic spiral is, that if lines be drawn from its centre, making equal angles with each other, the lengths of the several successive lines, terminated by the centre and curve, are in geometric progression. Hence, if we would trace an Ionic volute according to this principle, it will be only necessary to know the whole height, and the position of the centre of the spiral; but, as there may be an infinite number of such spirals formed with the same data, and all are not equally elegant, it becomes necessary to make a choice among them before the rule is applied. In the two examples above-mentioned, there are three complete revolutions of the spiral, besides the circle which forms what is called the eye of the volute; and to produce a figure resembling one of these, it will be necessary to fix the position of the centre of the volute so that its whole height, which we may suppose to be given, shall be divided by the centre in the ratio of about 1.6 to 1, or of 8 to 5. In the Erectheum that ratio is 1.588 to 1, and in the Temple on the Ilyssus, it was 1.621 to 1; the ratio which we have chosen is nearly a mean between both, and the larger space is to be above the centre.

In describing such a volute, then, it will be necessary to divide the given height in that proportion; by this the centre is determined; then, from this point, draw any number of lines at pleasure, making equal angles with each other, and find a mean proportional between any two of them which are known or have been determined, it will be the length of that line which is equidistant from both. Thus A B (pl. vii. fig. 7.) being the given height, and C the centre of the volute, and the several lines C A, C E, C D, &c., making equal angles with each other, a mean proportional between

C A and C B will give the length of C D; a mean proportional between C A and C D will give the length of C E, &c. A third proportional to C D and C B will give the length of C H; whence other mean proportionals may be found, and so on. These lengths may be all determined arithmetically and taken from a scale of equal parts; or they may be determined by any geometrical method, and a curve being drawn through the extremities of these lines, will form the required spiral. The interior spiral in the volute of the Erectheum may be described in the same manner, having assumed any one point through which it is to pass; and the same thing may be said of the spiral curves which form the fillets.

When we consider the high state of the inventive faculty among the Greeks, we are tempted to believe that they may have been acquainted with some of the scientific properties of this curve which was, so many Ages after they first used it, invented, or reinvented in the Northern parts of Europe; for we can hardly suppose that they traced the curve at random, though they may have adopted it as an Architectural feature from a perception of its beauty alone.

Several methods have been proposed for describing these volutes by compasses, on the supposition that a quarter of each revolution of the curve line is a quadrant of a circle; it is evident, however, that this was not the method of the Greeks, since no part of their volute is circular except the eye at the centre; and it may be doubtful whether the finding the centres for describing the quadrants is not more troublesome than the strict geometrical method above shown. If, however, the method of circles should be preferred, that invented by Mr. Goldman, which will be explained when we come to the description of the Roman Ionic Order, seems the most perfect, and may be employed.

With respect to the capitals of the Corinthian columns, it is, obviously, needless to assign any measures to the parts that compose them, on account of their variety and the minuteness of their divisions; the tracing of them must, therefore, be left to the judgment and taste of the artist.

CHAPTER IX.

Description and Character of the Egyptian Edifices.

Extent of the remains of Egyptian Architecture.

The reasons have been given why we began with an account of the Grecian Architecture, though we were willing to admit that, in the simplest state of the Art, this might not be the most ancient. We proceed, in the next place, to exhibit a sketch of what is known of the Architecture of Egypt and Asia previous to the time of Alexander, when that manner of building, which before seems to have been general in the East, was partly superseded by the more scientific and elegant styles of Europe.

The ruins of the Egyptian buildings extend, at intervals, along the banks of the Nile, in a valley fertilized by its overflowings from the Island of Philæ near Syene, in about the twenty-fourth degree of North latitude, to the shores of the Mediterranean, comprehending a line of about five hundred miles in length; and of these ruins, if we may form a judgment from the comparative rudeness of the sculpture, those about Thebes, or, as it is now called Medinet Abou, situated in about 25° 40′ North latitude, are more ancient than any of the others.

Monuments of Architecture, similar to those of Egypt, have been traced through Nubia and into Ethiopia, as far as two hundred leagues to the South of Philæ. Those in Nubia are inscribed with the characters of the Princes who appear to have constructed the edifices of Thebes: but the dominion of these Princes, perhaps, did not extend more than one hundred leagues to the South of Philæ, as, beyond that distance, the inscriptions indicate the names of Sovereigns unknown to Egyptian History.

Ancient splendou Thebes i Egypt.

At what time Thebes became the seat of the Egyptian Empire is not known. Osymandias is the first Sovereign whose History bears any marks of probability, but, of the time in which he reigned, we know nothing more than that it must have been long anterior to that of Homer; though the generally received opinion is that he lived 2270 years before Christ. According to Strabo, this Prince had a Palace at Thebes of great extent; the entrance was by an immense court, and, adjoining to this, was a long portico with a roof supported by animal figures; this led to another court more enriched than the first, and containing three enormous statues. He had also a Tomb, at the same place, ornamented with figures relating to Astronomical subjects, which were enclosed in a circle of gold. It is evident, therefore, that the public buildings of Thebes must, even in that remote Age, have possessed great splendour, and that the Arts must have arrived at considerable perfection.

Homer describes Thebes as a place of great magnitude and importance in his day. But, as the Egyptian cities seem to have been without walls, the hundred gates, by which the ancient Poet designates it, must have been merely such as formed the portals of the Temples or other public buildings. It was the successor of Cetes or Proteus, the reigning Monarch in the time of Homer, who, according to Herodotus, constructed a strong edifice to secure his treasures, which were secretly removed from thence by the Architect or his brother.

Few re- mains Greek Roma buildin Egypt.

About five hundred and twenty-five years before the commencement of the Christian Era, Egypt was conquered by Cambyses, and, from that time, the splendour of the nation declined; two hundred years after this it was again conquered by Alexander the Great. The style, however, of the Temples erected during the reign of the Ptolemies, nearly resembles that of the more ancient ones, and, probably on account of the great durability of all the public edifices, it would not often be found necessary to erect new ones subsequently to that time; consequently, though the old manner of building ceased to be practised, little opportunity would be afforded for the introduction of the Greek or Roman Architecture in the Country, and this may account for the few remains of buildings erected in either of those styles in Egypt.

The expedition of the French army into Egypt gave the scientific persons who accompanied it, an opportunity of examining the structures which remain in that Country after a lapse of, probably, three thousand years; and this good, at least, resulted from the expedition, *viz.* that we are become acquainted with those remains many years before we should have obtained that knowledge from the researches of solitary travellers, who would not have had the means of accomplishing what was done under the protection of a powerful army. It is chiefly from the great Work of Denon that we are able to state what is known of the Architectural works of the Egyptians; though, since that Work was published, much important information has been obtained from the researches of several enterprising individuals who have visited that Country.

Of all the great Pyramids the bases are square; the length of each side of the largest is about 700 feet, and its height about 450 feet. On the sloping surface are steps which lead to the top, where there is a square platform about 30 feet in extent each way. The lengths of each side of the bases of the second and third Pyramids are 650 feet and 280 feet, respectively. The height of the former is about 400 feet, and of the latter 160 feet.

In order to form the pile, the sides of the natural rock upon which it was founded were cut in steps, and the stones were disposed about and upon these, to the required extent, being raised to their places by a very simple contrivance, which is described by Herodotus. (*Euterpe*, sect. 125.) He says, they placed on the ground, under the block of stone, two levers, by which the stone was elevated to the lower step; then two other levers were placed under it to raise it to the next step, and so on, by which means the Pyramid served for its own scaffold. This contrivance shows that, in those days, the builders must have had some knowledge of one of the mechanical powers; though, most probably, they depended less upon machinery than upon the united labour of many persons. The whole exterior seems to have been intended to be faced with stone, in such a way that each side might form a smooth inclined plane: the revetment was begun from the top and completed by working downward; and the passages and chambers were probably formed as the work advanced. According to Herodotus, the lower part of the second Pyramid was covered with Ethiopian marble of various colours.

The faces of all the Pyramids are invariably turned towards the four cardinal points of the horizon; the entrances are on the Northern sides, and passages, inclining downward, lead to the chambers where the dead are deposited. The roofs of these chambers are formed by simply laying long stones across from one wall to the opposite, or where the breadth of the chamber was too great, the roof stones rested upon columns in the interior. The roofs of the passages are, in some cases, formed by laying stones horizontally above the side walls in two or more courses, the interior extremity of each stone projecting beyond that below till the courses on each side meet together at the top, as in the gallery of Tirynthus before mentioned. In other cases, the roofs consist of blocks of granite resting on the side walls at one end, inclining towards each other, and meeting in an angle at the top.

The disposition of their galleries and chambers may be understood from the following description of the interior of the Pyramid raised by Cephrenes, which is taken from the account given by Mr. Belzoni, who lately reopened it.

The entrance is on the Northern side, and the first passage is built of granite, but the rest are cut in the natural sandstone rock, which rises above the level of the basis of the Pyramid; this passage is 104 feet long, 4 feet high, and 3.5 feet wide; it descends in an angle of 26°, and at the bottom is a portcullis; beyond this is a horizontal passage of the same height as the first, and at the end of 22 feet it descends in a different direction, and leads to some passages below. Hence it reascends towards the centre of the pyramid by a gallery 84 feet long, 6 feet high, and 3.5 feet wide, and leads to a chamber, which is also cut out of the solid rock. This apartment is 46 feet long, 16 feet wide, and 23.5 feet high, and contained a sarcophagus of granite 8 feet long, 3.5 feet wide, and 2.25 feet deep in the inside. Returning out of this chamber to the bottom of the gallery, there is a passage which descends at an angle of 26° to the extent of 48.5 feet; at this place it takes a horizontal direction, and continues so for 55 feet, when it ascends again at the same angle, and proceeds to the base of the Pyramid, where another entrance is formed from the outside. About the middle of the horizontal passage, there is a descent into another chamber, which is 32 feet long, 10 feet wide, and 8.5 feet high.

Temple at Apollinopolis Magna.

At Apollinopolis Magna, near Edfou, about 20 miles South of Thebes, is a Temple, one of the largest in Egypt, which, at the same time, possesses considerable simplicity of character and remains to this day in excellent preservation. It is of a rectangular form, 450 feet long and 140 feet wide. The entrance is in the centre of one of the short sides, which is constituted by two masses of building, each 100 feet long and 32 feet wide; both are of a pyramidal form, and lie in the same direction, with an interval between them 20 feet wide, forming a passage which has a doorway at each extremity. This passage leads to a quadrangle, 140 feet long and 120 feet wide, with twelve columns on each side toward the right and left, and eight on the side adjacent to the entrance, all placed at a few feet from the walls toward the interior. The space surrounded by the columns is open above, but the passages between the columns and the walls are covered by a flat roof. On that side of the quadrangle which is opposite the entrance is a covered portico, extending the whole breadth of the quadrangle, and 45 feet in depth. This is enclosed by a wall in the rear and on each side, but is open in front; it contains three parallel rows of massive columns, six in each, and is covered by a flat and ponderous roof. A doorway through the rear wall leads to the body of the Temple, which is also a rectangle, 200 feet long and 98 feet broad, enclosed by walls and covered by a roof. No light seems to have been admitted to this part of the Temple, except from the door; and an exterior wall has been built on three sides, at a little distance, leaving an uncovered corridor between it and the walls of the Temple.

The exterior surface of the walls of the building is covered with figures, and in the interior of the masses at the front of the Temple are chambers and staircases; the latter leading to the roof. All the walls of the building incline inward like the sides of a Pyramid, and the upper extremities, as well as the edges formed by the meetings of every two faces, are ornamented with reed-shaped mouldings. The columns are of a cylindrical form, surrounded by horizontal mouldings at intervals, like rows of cordage, and crowned by bell-shaped capitals adorned with leaves of various forms; and above them is a plain architrave. The walls of the Temple and the architrave of the peristyle are crowned by an inverted cavetto, whose upper extremity projects over the lower: the face of this moulding is ornamented with triple reeds, in vertical planes, at certain distances from each other, and the intervals are filled with sculpture. See pl. ix. figs. 1, 2, and 3.

The Temple at Karnac.

The site of ancient Thebes is covered with ruins on both sides of the Nile; on the Eastern side are two villages, called Karnac and Luxor, situated about two miles from each other, where those ruins are most numerous; and the greatest edifice in Egypt is a Palace, or Temple, whose remains exist at the former of those places. Its general plan is one simple rectangle, and it consists of several apartments and courts, separated by walls extending quite across the Temple. The entrance is at the extremity of one of the short sides, and in front are two masses or towers of masonry, 140 paces long and 25 paces wide, exactly similar to those in front of the Temple at Apollinopolis. A passage between the adjacent extremities of these masses leads to the first court, which is rectangular, and 110 paces deep. This court is crossed by two rows of columns, at the extremity of which are two other masses disposed similarly to those in front of the Temple; and a passage between them leads to the next court, which is 78 paces deep, and entirely filled with 126 columns, disposed in nine parallel rows across the Temple. Beyond this is another court, containing several apartments besides obelisks, and colossal figures; and lastly, from this is an entrance to a vast quadrangle, nearly square, the central part of which is surrounded by a double colonnade; and between this and the exterior walls are the apartments for the Priests attached to the Temple, if it was one; or for the Monarch and his attendants, if the building has been a Palace. Adjacent to this are many other buildings of great extent, connected with it by avenues of sphinxes, lions, and rams, some of which extend as far as 1200 yards, towards Luxor.

In front of the mass, through which is the entrance to the Temple, or Palace, are colossal statues, and the exterior of the mass is decorated with paintings, representing battles, sieges, and triumphs. Among the ruins of this Palace is said to be a portion of a building still more ancient than that which now exists, and bearing inscriptions indicating the name and title of a King, whom M. Champollion supposes to be Osymandias himself.

Temple at Luxor.

Near Luxor are the remains of another building of a nature similar to that at Karnac, but of a less simple plan. At one extremity are, as usual, two great pyramidal masses of masonry, each 98 feet long and 90 feet high, placed both in the same direction, with an interval of 20 feet between them. In front of these towers, and on each side of the interval between them, is an obelisk of a pyramidal form, 12 feet square and nearly 100 feet high, and covered with hieroglyphics; and the interval forms a passage leading to a rectangular peristyle which has been enclosed by walls. In front of the entrance is a doorway, crowned by a cavetto, with a winged globe over the centre, and on each side is a colossal bust standing on the ground. Beyond this is an avenue 18 feet wide, between two rows of columns, 56 feet in height and 9 feet in diameter, which leads to an avenue 120 feet broad, in the same direction as the former, and consisting of two double rows of columns, 30 feet high and 4 feet diameter. At the extremity of this is a covered portico enclosed by two side walls, and forming a sort of pronaos to the building beyond; the portico is filled with thirty-two columns disposed in four parallel rows. This leads to the body of the Temple, which consists of several small square enclosures, or chambers, communicating with each other, and whose roofs are supported by columns in the interior.

Ruins a
Medinet
Abou.

On the Western bank of the Nile, opposite Luxor, is an immense statue of red granite, which is said to have been thrown down by Cambyses; between this and Medinet Abou, which is about 1¼ mile from it, the ground is covered by colossal statues, two of which are seated on pedestals, and are said to be the largest in Egypt. At Medinet Abou are the remains of a Palace, or Temple, in front of which is a rectangular peristyle, 55 paces long and 65 broad. The columns are 45 feet high and 7 feet diameter, and of better execution than most of the works in this place; on the exterior of the walls is a bas-relief, representing a chase of lions, and an invasion of enemies, who by their dress seem to be Indians. Near this place are situated the Tombs of Osymandias, and of the other Kings of Egypt, which are mentioned by Strabo.

Temple
Tentyris

The Temple of Isis, at Tentyris, or Dendra, on the Western side of the Nile, about 30 miles to the South of Thebes, is also one of the most complete yet remaining in Egypt. The plan of the exterior walls is a double rectangle, of which the first forms the vestibule; this is 160 feet wide and 90 feet deep, enclosed by a rear and two side walls, and covered by a roof. In front are six cylindrical columns, 55 feet high and 7 feet diameter, the capitals of which consist each of four female heads supporting a cubical block under the architrave; and in the interior are eighteen similar columns disposed in three parallel rows. The spaces between the exterior columns are each filled by a wall 26 feet high, except that in the centre, where there is a doorway; and the ceiling is painted with zodiacs. The second rectangle, which joins the rear of the vestibule, is 115 feet wide and 180 feet deep, and serves as a peribolus, or enclosure, to the apartments of the Temple itself. In the rear wall of the vestibule before mentioned, is an entrance to a square hall, 55 feet long in each direction, and covered by a roof which is supported by six columns in two parallel rows; the capitals of the columns are formed by heads similar to those of the vestibule. Beyond this hall there are two others in succession, of the same breadth, but each is only 18 feet deep, and from the last there is an entrance to the sanctuary, whose breadth is 24 feet and depth 40 feet. In the second hall are two staircases leading to the roof, or terrace, upon which is an apartment 9 feet square, having a zodiac painted on the ceiling.

About this Temple are three others, one of which appears to be unfinished; a circumstance from which we may perhaps conclude that the Temples of Tentyris are among the latest specimens of the ancient Egyptian Architecture. And from the Greek inscriptions found among the ruins, it is probable that the Architecture has suffered some modification from the intercourse subsisting between the two people. Elevations of a doorway and of one of the columns belonging to this Temple are given in pl. ix. figs. 4 and 5.

Templ
Latop
Philæ
Eleph

Near the same place, and at the village of Esne, on or near the spot where the city of Latopolis is supposed to have stood, are the remains of a Temple of Jupiter Ammon, consisting of a portico enclosed by three walls, and containing twenty-four columns disposed in four parallel rows. The capitals are bell-shaped, and ornamented with leaves, and above each is a plain cubical abacus supporting the architrave: the shafts are fluted in part of their length, and the lower part is rounded so that the foot is less in diameter than the part above. The columns stand upon plinths, and between every two is a wall 18 feet high. The whole column, including the plinth and abacus, is 42 feet high, and its diameter 6 feet.

At the Southern extremity of Egypt, near Syene, are the two Islands Philæ and Elephanta, in which are the remains of several Temples. The famous Nilometer, or chamber, containing a column for ascertaining the elevation of the waters of the Nile, was in a Temple dedicated to Horus, or Apollo, in the latter of these Islands. The Temple of Isis and Osiris, at Philæ, resembles the rest of the Egyptian Temples, but in front of it is a rectangular space, without roof, enclosed by three walls. Its length is 492 feet and breadth 157 feet, and there is an interior colonnade at a little distance from each of the side walls.

At Ypsambul, in Nubia, near the second cataract of the Nile, is a great Temple, buried about two-thirds of its height in the sand, which has been for many Ages accumulating about it. With incredible labour Mr. Belzoni made an excavation, by which he obtained access to the interior, and from his description we have the following account. The Temple is 117 feet wide and 86 feet high, and the entrance is by a large pronaos, 57 feet long and 52 feet wide, whose roof is supported by two rows of square pillars about 5½ feet broad; each pillar has a figure on it, finely executed, and very little injured by time, and the top of its head-dress reaches to the ceiling, which is above 30 feet high. Both pillars and walls are covered with beautiful hieroglyphics, exhibiting battles, storming of castles, triumphs over the Ethiopians, sacrifices, and the like. The second hall is about 22 feet high, 37 feet wide, and 25½ long; it contains four pillars, about 4 feet square, and the walls are covered with hieroglyphics. Beyond this is a shorter chamber, 37 feet wide, in which is the entrance to the sanctuary. At each end of this chamber is a doorway leading into smaller chambers, each 8 feet long and 7 wide, in the same direction as the sanctuary. The latter is 23½ feet long and 12 feet wide: it contains a pedestal in the centre, and at the end four colossal sitting figures, the heads of which are in good preservation.

Before the entrance are also four sitting figures, whose heights are about 51 feet, not including the caps, which are 14 feet high. On the top of the door is a figure of Osiris, 20 feet high, with two colossal hieroglyphic figures, one on each side, looking towards it. The Temple is crowned by a cornice 6 feet high, ornamented with hieroglyphics, and under it is a torus and architrave, the latter of which is 4 feet high. Above the cornice is a row of sitting monkeys, 8 feet high and 6 feet broad across the shoulders. The Temple seems to have had a fine landing-place from the river, but this is now buried under the sand.

The era of the greatest splendour of the Egyptian Monarchy seems to have been that which extended from the expulsion of the Palli, or Shepherd Kings, to the reign of Sesostris, and the greater part of the more ancient edifices are thought to have been the works of that Age. The hieroglyphics in rings, discovered by Mr. W. Bankes, among the subterranean ruins of Abydus, near Thebes, have been shown to express the names of Kings who reigned within the same period.

The more ancient buildings of Egypt seem to have met with the fate of many of those in Greece and Rome; that is, their materials have been employed in the construction of works subsequently erected; this has been the case, at least, with those about Thebes, as may be inferred from the paintings, sculptures, and hieroglyphics, on some of the masonry, which belong to a period more ancient than that of the present existing structures.

Strabo's description of the Egyptian Temples.

The description which is given by Strabo, in his XVIIth Book, of the Egyptian Temples, is nearly verified by the accounts we have of the remains existing at the present time. He says that, at the entrance was a paved court the length of which was three or four times its breadth. Within this were plantations, and it was ornamented with sphinxes. At the extremity of the alley of sphinxes was a vestibule, or propyleum, which led to another court, and at the extremity of this was a second portico, which led to a third court: all these courts were surrounded by galleries. The body of the Temple was divided into the pronaos and the *secos;* the latter of which corresponded with the naos of the Greek Temples. On the two sides of the pronaos were pteromata, or walls like wings, of the same height as the Temple, and ornamented with figures. The secos was small, and contained the image of the God, or the sacred animal which was the object of worship. It was surrounded by chambers for the lodgings of the Priests, or of those who had the care of the Temple.

General characters of the Egyptian Temples.

Of the Egyptian Temples it may be said that they are characterised by uniformity of plan, elevation, and decoration. That at Karnac is a simple rectangle, but in that at Tentyris, the walls of the portico project laterally beyond the side walls of the Temple. The one at Luxor consists of several squares or rectangles clustered together, nearly in the form of a double cross, and the sides are situated obliquely with respect to the directions of the avenues of columns by which the Temple is approached, as if to avoid some defects of ground. They are distinguished from the Greek Temples by having flat roofs; which being formed of solid stone-work, the blocks could not always be obtained of sufficient length to rest on the walls of the larger apartments; consequently it was necessary to place columns in the interior, for the support of the roofs; and these, in some cases, are so numerous as to look like a forest.

In the Egyptian Architecture almost every consideration yielded to that of strength, though beauty was not neglected, and the edifices of that Country possess a species of magnificence from their bulk, independently of the delicacies of Art with which many of them were adorned. The quarries of Egypt afforded blocks of the greatest size; and the labour of a multitude of slaves, aided perhaps by the simplest of the mechanical powers, accomplished the removal of the heaviest masses to their place of destination. According to Herodotus, the stone which served for the roof of the Temple of Latona, at Butos, was forty cubits long in each direction; and if we suppose the cubit to be equal to 20½ inches, that block must have contained above 300,000 cubic feet of stone. This enormous mass was transported on rafts, from the Island of Philæ to Butos; a space of 150 leagues.

Manner of constructing the Egyptian Temples.

Calcareous stone was generally employed in the walls of buildings, and granite in the obelisks and statues. The skill of the workmen was exhibited in squaring the blocks with precision, and fitting them accurately with each other. Plugs of wood seem to have been occasionally employed to connect them together, but there is no appearance that metallic cramps were used for that purpose: nor was the Art of constructing vaults at all known to this people. The hieroglyphics and figures were sometimes executed in relief, but generally they were sunken and embellished with colours.

None of the Works hitherto published give any notion of the rich and elegant decorations of some of the Temples, the ornaments of which are nearly as various as those of the Grecian edifices; but we have been favoured with a sight of the drawings executed by Mr. Charles Barry, when in Egypt, which, it is to be hoped, that gentleman will one day communicate to the public: from these it appears, that not only the exterior and interior surfaces of the walls of the buildings, but the soffits of the porticos, the beams and intervals between them, were richly ornamented with sculpture, painting, and gilding.

The walls of the Temples invariably have their exterior faces considerably inclined at top towards the centre, so that the figure of the whole edifice resembles a frustum of a Pyramid. This seems to have been intended chiefly for stability, but perhaps partly, as is observed by M. Quatremer de Quincy, to diminish the breadth of the building at top, in order to suit the lengths of the stones which were to cover it. Still further, for the same object, the workmen sometimes placed courses of stone along the tops of the walls, the upper projecting over the lower towards the interior, like inverted steps.

At all the angles formed by the faces of the walls, instead of leaving a sharp edge, the artists executed a reed moulding, equal to about three-quarters of a cylinder, with lines cut obliquely upon it, very much resembling a pole having a string wound about it; and the same kind of moulding was continued, horizontally, along the tops of the walls. This seems to have been an imitation of the system of poles which might have been originally constructed to form an outline of the edifice, and guide the workmen in building the walls; though, possibly, it might have originated in the desire to ornament the angles, as the Greeks, for the same purpose, employed pilasters, and the Italian artists rustic quoins. The tops of all the walls were crowned by a sort of cornice, of a concave form on the exterior, and having its summit projecting forward; the front of this member was covered with sculpture, generally resembling a series of reeds parallel to each other, and directed from top to bottom; and both the exterior and interior faces of the walls were covered with hieroglyphics.

The pronaos was roofed and enclosed by walls on all sides except the front, where the first row of columns stood between the extremities of the two flank walls; the exterior angles of the front were inclined, as has been said, but those terminations of the front which were next to the two outer columns of the row were vertical. Between the columns, and up to about half their height, a wall was constructed from which the lower parts of the columns appeared to project as much as half their diameter; the wall was adorned with sculpture, and was terminated by the usual cavetto or curved cornice, but it was interrupted between the two middle columns to form a doorway.

The towers and portals.

Generally, in front of the Temple, were one or two of those towers, or masses of masonry, mentioned in speaking of the Temples at Karnac and Luxor; these also were tapered toward the top, the reed moulding was cut at the angles, and the whole was crowned by a cavetto and covered with hieroglyphics. A pair of obelisks, or statues, was frequently placed in front of the passage cut through these masses; and within the latter were staircases which led to the platforms on their tops; these staircases were always directed straight forward, or the parts were made to turn at right angles to each other. No reason can be given for the formation of such immense masses of masonry, except it be that the artists of the Country intended to produce a grand and striking effect by a vast accumulation of materials as well as by the forms of their edifices. Two of these towers were generally placed in the same direction at a little distance from each other; and, in front of the interval, was a portal constituted by two jambs and a lintel; the exterior and interior edges of the jambs were generally made to incline inward like the walls of the building itself, though sometimes the interior edges were vertical. The faces of these members were adorned with a great profusion of hieroglyphics; a reed moulding surrounded them on the exterior, and the lintel, like the building itself, was crowned by a cavetto ornamented with sculpture. On the centre of the lintel was, usually, carved a scarabeus or beetle, or, sometimes, a globe having a wing on each side.

Windo

Where windows occur, they are, generally, in the shape of a long square without any ornament, but splayed on the interior side. The windows of Egyptian Temples are, almost in every case, extremely small; and the only example, perhaps, in which they approach the magnitude and proportions of those found in Grecian or Roman buildings, is the Temple at Dendour in Nubia; and, probably, this is the work of a late period of Egyptian Architecture. Its outline is pyramidal, as usual, and in the façade is a doorway crowned by a cavetto; but, above this, are three rectangular windows occupying nearly the whole breadth of the façade. Over the middle one is the winged globe, and the whole pier between the two windows has the form of a pilaster with a capital resembling those of the Corinthian Order. The capitals do not reach to the level of the tops of the windows, and appear as if placed there, in bad taste, for no purpose but that of ornament.

Ceilin

The ceilings of the Egyptian buildings are generally smooth; but, in some cases, they seem formed in hollow panels by the architraves of stone, which cross each other at right angles over the tops of the columns. Frequently there are traced upon the ceilings what are called zodiacs; that is, representations, *in plano*, of the zodiacal constellations, disposed in a circular order about the centre of the compartment. From the positions of these constellations, an effort has been made to ascertain the dates of the construction of the edifices in which they are found; but nothing satisfactory on this head has yet been elicited.

The simplicity of the forms of Egyptian buildings has led some persons to suppose that the workmen might have dispensed with any previous design like that, which, in the edifices of other Countries, is necessary to guide them in the execution; and it is the opinion of M. Denon that the Temples were entirely constructed by the eye, and according to a routine established among the builders, who, he observes, were unembarrassed by any adjustment of the members of the frize or cornice, or by any care of providing against a lateral thrust in their roofs.

Form the Eg colum

That the Egyptian columns were copied from the form of certain trees is probable, not only from their appearance, but from the testimony of Herodotus, who says, (*Euterpe*, sect. 171.) that King Amasis actually caused columns to be made resembling palm-trees. They are without bases, or have only a plinth, and that is frequently circular. The capital is generally of the bell-shape, and is either quite plain, or is ornamented in several different manners; frequently it is surrounded by rows of lotus leaves, either simply marked by lines, or sculptured in relief; in the latter case, the capitals resemble some of those of the Corinthian Order. On the columns of the Temple at Philæ, the capital is sculptured to represent three rows of plants, the tops of which are like palm-leaves; and in some examples, as in the Temple at Tentyris, it has the form of a female head. But, what is very different from the practice of the Greeks, is that in the same building, and even in the same row, the capitals of the columns do not resemble each other. In the Egyptian Temples the intercolumniations are generally small, not exceeding 1.5 diameters.

The height of the column, from the bottom of the plinth to the top of the capital, is equal to from three to eight diameters, and the tallest column is above fifty feet high; in some cases the shaft diminishes gradually from bottom to top, and is sculptured as if it were a bundle of reeds bound together, at intervals, by three or more turns of cordage; these intervals are either plain, channelled, or reeded, and sometimes all the three kinds exist upon one column. Two circumstances are peculiar to the Egyptian columns; the first is, that there are often cubical blocks of stone between the capitals and the entablature; and the second, that the lower part of the shaft is sometimes cut away, so that the part which rests upon the plinth is smaller than the part above; such is the case with the columns of the Temple at Latopolis. It is difficult to assign any reason for the latter practice, since it can only tend to weaken a column in a part where it ought to be the strongest; the lower parts of these columns are rounded and ornamented with sculptured foliage, which makes them appear as if they stood upon the roots of plants. In other instances the upper part of the column swells out from the shaft suddenly, and then tapers again to the top, making it resemble a post crushed by a weight above; and, that the form has been adopted from observing some such effect seems evident, because under this swell there are mouldings, resembling cordage, about the column, as if to prevent its splitting further by the weight. The most remarkable example of this kind of column is that observed by Mr. Barry in the interior of the Tombs at Benihassan, about forty-eight leagues South of Cairo; he compares each column to a bundle formed by four large reeds of the Nile placed upon a plinth and tied together by cords near the top; small sticks are introduced between the reeds at the place of ligature, to render the column more circular, and afford the means of firmly tying the whole together. See pl. ix. fig. 6.

The porches of the Tombs at Silsilis, about seventy miles South of Thebes, are formed by columns of a similar nature; but the same gentleman also observes, that the fronts of two of the Tombs at Benihassan consist each of two fluted columns resembling those of the Doric Order, one on each side of the entrance; the columns are about 5½ diameters in height; the flutes are shallow and twenty in number; the capital consists of an abacus only, and there are no indications of a base or plinth. Above the architrave, which is plain, is a projecting ledge of the rock, in the form of a cornice, the soffit of which is sculptured, apparently in imitation of a series of reeds, laid horizontally, for its support.

Mr. Barry gives another instance of fluted Egyptian columns in an excavated Temple at Kalaptchic, about twenty-five leagues above the first cataracts. The Temple consists of two chambers, and the roof of one of them is supported by two such columns; their shafts are each 7.667 feet high, and 3.167 feet diameter, with a slight diminution upward: they have a square abacus and a circular plinth. In a Temple at Eleuthias, a few miles South of Esne, is a large vestibule whose roof is supported upon polygonal columns of sixteen sides. (Gwilt's edition of Chambers's *Architecture*, p. 37. note.) In the Egyptian buildings there are no pilasters, properly so called, except the small ones in the sepulchral chamber of the great Pyramid; but, sometimes, human figures are placed as columns, either alone, or, as it were, attached to the fronts of square piers, of which the Temple at Ypsambul, described by Belzoni, affords examples. It is observed by Mr. Forsyth that, in general, the Egyptian statues are well adapted for the support of an entablature, their backs are flattened as if for the purpose of adhering to a wall; their arms are placed close by their sides, and the head is secured to the body by broad tresses which fall down on the shoulders and breast.

The entablature.

In general, the entablature of the Egyptian buildings consists of an architrave, either plain or ornamented, with a cornice over it; but in some examples, as in the Tombs of Silsilis, the entablature consists of an architrave, frize, and cornice, each projecting over the one below it, like an inverted step; the upper part of the cornice projects still further, and the projection is supported by a sort of modillon. The height of the entablature is about one-third of that of the columns. Over the architrave of the interior range of columns in the great Temple at Karnac is a wall with rectangular perforations, like windows, immediately over the intervals of the columns below.

Above the capitals of the Egyptian columns is an abacus, sometimes resembling that of the Greek Orders; but, at other times, it consists of a cubical block, either plain or sculptured. Over these blocks is placed the horizontal beam parallel to the line of columns, and corresponding to the architrave of the Greeks: and above all, is what may be called the cornice, the section of which is concave outward, and which has its top projecting beyond the face of the architrave. The concave front of this member is adorned with sculpture, in some cases consisting of a series of reeds parallel to each other from top to bottom of the cornice, in other cases the reeds are in groups of three or six in each group; the intervals, or metopes, if they may be so called, are sculptured with winged globes, as on the portico of the Temple at Tentyris. These reeds are disposed with regularity, but not over the middle of the front of the columns as in the Greek Temples; for, in the portico of the Temple at Latopolis, each group is equally distant from the next, and one is placed over the middle of the intercolumniation, but the middles of the other groups fall over the sides of the columns. The interval between every two groups is occupied by a channel cut in a vertical plane down the face of the cornice. The Egyptian reeds differ also from the Greek triglyphs in an essential circumstance, *viz.* that the latter are so situated as evidently to indicate the supports of the roof; whereas the others are ornaments in the front of the roof itself, above which there is generally nothing to be supported.

The entablatures are frequently sculptured with figures of animals, and it is possible that the zophorus or frize, in the Greek Architecture, received its name from this circumstance; winged globes and the scarabeus are, almost invariably, the ornaments of the Egyptian architraves.

The Architecture of Egypt scarcely applicable to modern edifices.

It was an observation of a French author, that there is nothing in the Egyptian Architecture conformable to the circumstances of the moderns; for, says he, we do not possess those immense blocks of stone which, in Egypt, are the motives, or excuse, for a style of building distinguished by being enormously massive; and he supposes that an imitation of their works on a small scale, or with materials of small dimensions, would inspire ridicule rather than afford pleasure. This observation, to a certain extent, may be just, but it would be improper to exclude the Egyptian Architecture entirely from the modern practice, as it is possible that there may be some cases in which it may be employed to advantage. That style has lately been adopted, with success, in the construction of an iron-foundry in Wales; and, if it were only applicable to such buildings as Manufactories, Prisons, or Tombs, it would contribute to the production of an agreeable variety in our Architecture.

CHAPTER X.

Ancient Edifices of Syria and Persia.

Temple at Aradus.

While the Egyptian Empire flourished, the style of its Architecture extended itself into Syria and, perhaps, still further towards the East. To this period may, perhaps, be referred the execution of a work which was observed by Pocock on the Island of Aradus, or, as it is now called, Tortosa. According to the description of that traveller, it is a court formed by cutting down the solid rock from top to bottom. In the centre of the court is a throne composed of four stones besides the pedestal on which it stands; one serves for the back, another for the canopy, and two others for the sides. Between these was, probably, placed the Idol worshipped in the court, which, no doubt, was a kind of Temple. In two of the corners of the court there appear to have been small apartments cut also in the rock.

The Temple at Jerusalem

In the sacred Scriptures is given an account of the construction of the Temple at Jerusalem by Solomon; from which we perceive that the plan of the building very much resembled that of the Temples of Greece or Egypt. According to the description in the Book of *Kings*, the plan of the Temple was a parallelogram; its length was 60 cubits, and its breadth 20 cubits, and it was divided into three principal parts by walls parallel to its breadth. There is some doubt about the precise value of the cubit here supposed to be employed, but assuming it to be equal to 1.824 feet, which is that generally assigned to it, it will follow that the length of the Temple was 109.44 feet, and its breadth 36.48 feet. In front was a pronaos or portico; then followed the cella, or main body of the Temple; and, thirdly, at the other extremity, was the sanctuary. The breadth of the portico was equal to that of the Temple, and its depth was 10 cubits, or 18.24 feet; the body of the Temple was 30 cubits, or 54.72 feet deep, and the sanctuary 20 cubits, or 36.48 feet. The height of the Temple, probably the middle part, was 30 cubits, or 54.72 feet; that of the sanctuary was 20 cubits, or 36.48 feet, and that of the portico, if we may judge from the height of its columns, was about the same. The latter was covered by a roof, and the body of the Temple was, probably, similar to that of the Greek hypæthral Temples; it was surrounded, in the interior, by three tiers of chambers, one above another, there was an ascent by stairs from the ground to the middle and upper stories, and the central space was a court open to the sky. The bells which were suspended about the Temple were, probably, intended, by the sound they produced, on being agitated by the wind, to keep off birds from the consecrated edifice. The like means are known to have been adopted, for the same purpose, on the roofs of the Grecian Temples.

The floors of the upper chambers were laid on beams of cedar, the ends of which were not inserted in the walls of the Temple, but rested on corbels of masonry attached to their faces. The interior of the walls was boarded with cedar, on which were figures of cherubim and palm trees sculptured and covered with gilding. Within the sanctuary were two figures of cherubs, made of wood and covered with gold; these were 10 cubits high, and their expanded wings extended across the breadth of the Temple.

In front of the portico and between the extremities of the side-walls, were two brass pillars, each 18 cubits high and nearly 4 cubits in diameter; the chapiters, which may mean either the capitals of the columns or the whole entablature, were also of brass, and 5 cubits high, ornamented with wreaths and leaves of pomegranates or lilies, and covered with network. Pillars are also mentioned whose capitals were only 4 cubits high; probably these were within the portico, and formed part of the support of its roof.

The house of the forest of Lebanon seems to have been similar to the Temple, but more extensive, being 100 cubits long and 50 broad. It had a portico in front, the breadth of which was equal to that of the house, and the depth 30 cubits; its roof was supported on four rows of pillars of cedar wood, fifteen in each row.

The height of the columns of the Temple being equal to about five diameters, the proportions are nearly the same as those of the Egyptian and earliest Greek examples, and the capitals bear a considerable resemblance to those of the former Country.

Persia was the seat of a powerful Empire, from the time at which Nimrod built the city of Babylon till the invasion of the Country by Alexander the Great; and during that period the Art of building must have been practised there to a great extent. The frequent changes, however, which the Government experienced, and perhaps other circumstances with which we are unacquainted, have caused the destruction of nearly all the monuments of the Architecture of this highly civilised people; indeed, if we except the ruins at present existing in one place, not a vestige of them remains. These ruins are found in the Province of Farsistan, a few miles to the North of Chyras, or Shiras, and are probably on the spot where the city of Persepolis anciently stood. This city, one of the Capitals of the Persian Kings, is supposed to have been built or embellished by Cambyses, or rather by his successors Darius and Xerxes; but its prosperity must have been of short duration; for with the other cities of the Empire, it declined after the death of Alexander and the division of the territories he had conquered.

Le Brun, to whom we are indebted for the description and measurement of the ruins, supposes them to be the remains of the Palace of Darius destroyed by the Macedonian Monarch in one of his revels: and the inequality of the ground, together with the appearance of distinct apartments for men and women, are more favourable to the opinion that the ruins have formed part of a Palace than of a Temple. This traveller observes that the whole of the edifice has been founded upon a marble rock, which has been levelled, and constitutes a platform about 400 yards long from North to South, and about half as much from East to West; and on the margin of the rock, there has been erected a wall surrounding the whole building, and following all the sinuosities of the ground. The Western side of the platform is elevated 22 feet above the plain in front, and there is an ascent to it by steps in two ramps, which first diverge from one another, and then come together at the top. The steps, which are about 4 inches high and 14 inches broad, lead, at about 42 feet from the edge, to two great masses of masonry, resembling those which are placed before the Temples of Egypt: like them, they diminish upward, and are crowned by a cavetto, the upper part of which projects over the lower. In them are formed doorways which, no doubt, led to the front courts of the Palace, the magnificence of which is attested by the number of broken columns which lie scattered about.

These masses are 22 feet long and 13 feet thick, but the height of one is 39 feet, and of the other 29 feet. On the sides are sculptured winged horses with human heads, wearing Persian dresses. The bodies of the horses are in bas relief, but the legs are detached from the wall, and the style of the figures indicates a taste for whatever was capricious and extravagant in sculpture.

Beyond this first assemblage of ruins, and to the right of the above-mentioned masses, is another assemblage upon more elevated ground, and seeming to form the principal part of the Palace. This terrace is supported by walls, on which are numerous sculptures representing processions and sacrifices of horses and oxen; several of the figures have the particular kind of head-dress and umbrella which were worn by the Persian Nobles, but others have long robes resembling those worn by the Medes. The proportions of the figures are good, but the execution is without taste, and appears to have been hasty. Near these are the remains of some subterranean vaults, which M. Le Brun supposes were intended to convey water to the Palace.

The columns are of grey marble, from 70 to 72 feet high and 5¾ feet in diameter; consequently, their height is equal to about 13 diameters; which appearing too slender to support a great weight, has led that traveller to believe that this must have been a summer Palace, roofed with timber, or having some temporary covering. Each column has a base, which is 4¼ feet high, with sculptured mouldings. Some of the columns are decorated with zig-zag ornaments, resembling those on the fragment found near the Treasury of Atreus, at Mycenæ; the upper parts of others are ornamented with several small scrolls which are not much unlike the spirals in the capitals of the Ionic Order. The shafts consist of four or five different pieces besides the capital, and some of them are fluted with as many as forty longitudinal channels, each about three inches wide, with fillets between them. A representation of one of these columns is given in pl. ix. fig. 7; and if we include in the capital all the scrolls, that member will occupy about one-fifth of the height of the column. On some columns are represented camels stooping; on others figures resembling horses. One of these is given in fig. 8, and the sculpture on one of the piers at this place is represented in fig. 9.

Persian or Parthian Tombs.

In some rocks, about two leagues from Persepolis, are formed excavations, which have been taken for the Tombs of the Persian or Parthian Kings; and from the view and description given by Le Brun, the following account of the ornaments about the façade of one of them has been taken. One side of the rock being cut away, a vertical front is formed, about 70 feet broad and as much in height; in the lower part of which is the entrance to a gallery. The sides and top of the entrance are cut in the rock, so as to form three faciæ parallel to the front, each deeper than the one on its exterior; and over the top is the Egyptian cavetto. Parallel to the front wall, and a little in advance, are four columns at intervals from each other, about equal to the breadth of the doorway, with capitals formed of the heads of oxen projecting beyond the columns. Over these, comes an architrave extending along the whole breadth of the front, and divided into three faciæ projecting beyond each other, upwards; above this is a kind of cornice, projecting about 2¾ feet, and supported by modillons. Upon the top of this is a wall, like a parapet, of the same length as the architrave, and sculptured with lions.

On the upper part of the rock, and attached to its front, are sculptured two rows of human figures about six feet high, one row above the other, and fourteen in each row. The rows are separated from each other by a sort of entablature, and another entablature is placed on the heads of the figures in the upper row. On the right and left of these rows is sculptured an upright figure about twenty feet high, having the head and feet of some animal, and the body forming an inverted frustum of a cone; and in the sides of the excavation of the mountain are three recesses, one above another, over the extremities of the portico, each containing statues. Above the two rows of figures before mentioned, is the figure of a man about fourteen feet high, standing on steps and holding a bow; an altar, with a fire on it, is before him.

The sculpture on some of these rocks represents, in bas relief, combats, in which the warriors are mounted on horses; this is not the case in the bas reliefs of Persepolis, and it is therefore probable that these Tombs are works of the Parthians, to whom Persia was at one time subject. A façade of one of these Tombs is represented in pl. ix. fig. 10.

From the resemblance of some of the features in the ruins of Persepolis to those of the Egyptian buildings, it seems probable that the Persian Architecture is derived from that of Egypt; and the Palace we have noticed has been supposed to be executed by artists of the latter nation, who were brought into Persia at the time of the invasion of Egypt by Cambyses. All the sculptured Tombs above mentioned bear the name of Naxi Rustan, or rather Neksha-e-Roostem; that is, the sculptures of the hero Rustan, or Roostem, the Hercules of the East.

PART II.

ANCIENT ARCHITECTURE OF THE ROMANS AND SARACENS.

CHAPTER I.

The Origin of Latin Architecture, and the oldest Temples of Italy.

Architecture cultivated by the Etruscans.

The people of Italy seem to have begun, at an early period, the cultivation of Architecture; and the ancient inhabitants of Etruria or Tuscany are said to have invented a particular Order, before any communication was established between Italy and Greece. But, though it is not meant to deny this fact, yet it is also possible that, as a colony of Arcadians are said to have, very anciently, established themselves, under Evander, in that Country, this colony may have introduced a mode of building which had been previously practised in Greece; and, in this case, the Order alluded to, which is commonly called the Tuscan, might be only a copy or modification of the very ancient Grecian Doric; which it, in some respects, resembles, if we may judge from the description given of it by Vitruvius. That the ancient Etruscans possessed a certain degree of taste and elegance in Art cannot be doubted, when we consider the remains of antiquity which have been discovered in their Country; and there is sufficient reason to believe that the Romans employed artists of that nation to execute their great works before they became acquainted with the more splendid performances of the Greeks.

Early buildings of the Romans.

Architecture was probably unknown in Rome till the time of the Tarquins; but that, from that period, the Romans had some acquaintance with the Art, and that their edifices were, even then, not entirely destitute of ornament, is rendered probable by the circumstances we are about to mention. The ancient Temple of Jupiter in the Capitol was begun during the reign of the elder of those Princes, by Etruscan workmen, though it was not finished till long afterwards. According to Cicero, it had two rows of columns in the interior, by which it was divided into three parts, longitudinally, and its front was crowned by a pediment. It might, therefore, resemble the Temples at Pæstum which have been already described, and, perhaps, was not inferior to them in magnificence. We learn from the same authority, that it was twice destroyed, and as often rebuilt upon the same foundations. According to Palladio, the ancient Temple of Vesta at Rome, which is supposed to have been built by Numa Pompilius, was of a circular form, and surrounded by columns whose capitals resembled those of the Corinthian Order which was, subsequently, so much employed in Roman buildings. Again, what Palladio calls the double Temple of the Sun and Moon, but which, it is now supposed, was dedicated to Venus and Rome, and which is said to have been built by King Tatius, or rebuilt at a subsequent period according to the original design, must, even in its primitive state, have possessed great magnificence of character. To these we may add the *Cloacæ*, or sewers at Rome, which bear marks of very high antiquity, if they were not executed by the elder Tarquin, as is commonly supposed. No doubt many structures for Religious and Civil purposes existed in Rome and Italy, during the times of the Monarchy and Commonwealth, which have since gone entirely to ruin; and it is probable enough that they possessed neither the stability nor the splendour of the Grecian buildings.

Invention the Comp site Orde in Italy.

From the time that a constant intercourse subsisted between Italy and Greece, the artists of the former Country laboured to copy the works of their more refined neighbours; and, not having sufficient correctness of taste to relish the simple beauties of the Grecian Architecture, or perhaps, being unwilling to confine themselves to the repetition of forms which already existed, they applied themselves to make variations in the style, and increase the embellishments of the different Orders. From this propensity to change has, no doubt, arisen the fifth, or that which is called the Roman or Composite Order, which consists in a union of the volutes of the Ionic with the foliage of the Corinthian capital.

It is supposed that this Order is alluded to by Vitruvius, in the Ist Chapter of the IVth Book, but he does not give any particular description of it; and, consequently, it has been doubted whether that which we describe under this name existed in his time; it is very likely, however, to be the production of some Roman artist who, in search of novelty, has found nothing better than a combination of the ornamental parts of two Orders already existing.

Roman A chitectu directed objects utility.

It was an observation of Strabo that the Romans excelled the Greeks in their attention to objects of the highest national utility. The latter people confined their Architectural labours to the embellishment of their Temples, the entrances of their cities, and their places of public exercise; while their private dwellings were mean, and, except the Palæstræ, every work which, in another Country, would be considered essential to the comfort of the people was, in Greece, disregarded, or, by the nature of the Country, rendered unnecessary. The former people not only gratified their piety or vanity by erecting splendid edifices for the Gods, but formed bridges and high roads for facilitating the communication with every part of the Empire; immense sewers to drain and purify their cities, and magnificent aqueducts to supply them with an abundance of that indispensable element, water.

Probabl that the was un- known t the Anci out of Italy.

One thing in particular there is reason to believe that Italy may value itself on, *viz.* the invention of the arched vault and dome, of which not a trace exists in any other Country of an earlier date than the time of its intercourse with Rome. And, though it is barely possible that the invention may have taken place in some part of Asia where, large masses of stone being scarce, it is to be expected that such a contrivance would be thought of, to form a cover to a building, or a bridge across a river; yet the total absence of examples the antiquity of which is authenticated, proves that the arch could not have been in general use, and even renders it probable that it was entirely unknown; since, if known, its obvious utility would necessarily have led to its frequent application.

In mountainous Countries natural appearances are not wanting which might suggest the idea of a curvilinear arrangement of materials constituting an arch; the entrances of caverns and the perforations of rocks frequently bear this form, and these have been imitated on some occasions at a very early period. Mr. Hamilton describes an artificial perforation like an arch, made in a solid wall, and serving as a doorway in an ancient Fort at Ephesus; but we do not mean to class under the name of arches such apertures as this, nor the covered passages described in speaking of the works at Mycenæ and the Egyptian Pyramids. These methods are nearly as old as the Art of building itself, and have been practised not only in Greece and Egypt, but also in Britain, in India, and in America. By an arch we mean a number of wedge-like stones disposed in a vertical plane, and sustaining themselves in the air by their mutual pressures. Of this kind of arch no vestige appears among any of the remains of the early Architecture of Greece; even the river Cephissus, which crosses the road to Athens, had no bridge over it till one was erected by the Romans when they had possession of the Country. The *tholos* mentioned by Homer and other Greek authors, and which is usually translated a dome, signified, as Lord Aberdeen observes, merely a building on a circular plan without regard to the roof, which, in works of that kind, is supposed to have been frequently of timber and of a conical form; and the roof of the monument of Lysicrates, at Athens, is merely a mass of stone resting vertically on the side walls of the building. The roof of the Temple of the Winds is that which approaches nearest to the character of a dome, being composed of twenty-four separate blocks which abut on a key-stone at the vertex; but the editor of Stuart's *Athens* does not consider them as exhibiting any feeling of the principle of the arch.

In Italy we find the earliest traces of arches, and, whoever was the inventor, the Romans have certainly the merit of bringing them into general use, and of employing them for the most important purposes. A work which is with reason considered as one of the earliest specimens of arches, is the conduit at Tusculum near Rome. This is a subterranean channel proceeding from a reservoir under a mountain; it has vertical sides and is covered by stones, in the form of frusta of wedges, abutting against each other at their oblique sides, in which construction the principle of the arch is distinctly exhibited. The reservoir is 10 feet broad, and 10½ feet high, and is formed similarly to the Treasury of Atreus, its sides being composed of circular courses of stones, horizontally disposed, and gradually contracting towards the vertex; which gives an antique character to the reservoir confirmatory of the opinion that the conduit is an original example of vaulting, and not a rude imitation of a more perfect form. (See Kinnaird's *Supplement* to Stuart's *Athens*.) Next to this may be mentioned the arches found in part of the ancient walls of Rome, built by Tullius, and the *Cloaca maxima;* the latter of which is formed of immense blocks of stone joined together without cement, and constituting a semicircular vault, as perfect as any subsequently constructed. These are generally supposed to have been built by Tarquin the Elder; and though Mr. Mitford thinks the present arches were executed in the time of Augustus, yet the Etruscan character of the workmanship renders the former opinion more probable. They are now nearly choked up with earth, but, during the prosperity of the city, they were large enough to admit a carriage laden with hay, and boats could pass through them.

We have no further knowledge of the employment of arches at Rome till we come to the time of Julius Cæsar, who erected the Theatre of Marcellus, on the exterior of which are rows of arches in good preservation. From the way in which Dion Cassius speaks of the erection of this Theatre, it has been supposed that it was an exact imitation of the Theatre which had been before built by Pompey; and it is also supposed that Pompey's Theatre was an imitation of one at Mitylene, erected in, or about, the time of Alexander. Now both Pompey's Theatre and that at Mitylene have disappeared; but as there are arches in the Theatre of Marcellus, it has been inferred that there must have been also arches in both the others; it must be owned, however, that this fact is far from being certain. It is true that there are some remains of Theatres in Asia Minor, in which arches are to be found, but it is believed that they were erected subsequently to the reign of Alexander; and, therefore, do not militate against the prior claim of Italy to the honour of the invention of both the arch and dome.

In speaking of the windows of buildings, Vitruvius, who probably lived about the time of Augustus, describes the construction of arches in an unequivocal manner, and it is evident, therefore, that they must have been in use before his time. In the XIth Chapter of the VIth Book, he says that the upper parts of the openings between the piers may be formed horizontally, or in an arc of some curve; and, he continues to observe, that if the materials are small with respect to the breadth of the aperture, they will neither stand in their places nor support an incumbent weight if they are made rectangular. He prescribes, therefore, that the arches should be made of wedges whose joints, or faces, tend towards the centre; by which form they discharge the weight above; and that the angular piers, or the piers forming the extremities of the wall, should be of greater breadth than those between the arches, that, by confining the wedges, they may give firmness to the work.

Rome embellished by Augustus.

In the time of Augustus we find a degree of magnificence in the Italian buildings beyond that which they had before attained. The conquest of nearly the whole of the then known World, and a general Peace, allowed the Sovereign to turn his thoughts to the improvement of his Country; a constellation of illustrious Poets and Philosophers at that time shone in the metropolis of the Empire, and gave the minds of the people a tendency towards subjects more useful and honourable than the conquest of remote and unoffending nations. With the other Arts, that of building was cultivated at Rome; Augustus himself caused to be erected several Temples besides other superb edifices, and so far changed the face of the city, that, in speaking of him, it could be said, "*marmoream se relinquere quam lateritiam accepisset.*"

The Architecture of Vitruvius written in the time of Augustus or Titus.

It is a generally received opinion that the celebrated Vitruvius wrote his Treatise on Architecture during the reign of this Prince, and, therefore, we may avail ourselves of his authority for an account of the style of building in use at that period. We know, however, that the precise time at which Vitruvius lived is uncertain, and the arguments in favour of that Work being written in the reign of Titus have considerable weight; yet this will be of little consequence, since Vitruvius describes buildings which had been executed, and delivers precepts which had been acted on, before his time, and therefore, in admitting the latter opinion to be correct, we shall still, by following him, be carried back to a period, perhaps even earlier than that of Augustus.

In the Proem to his VIIth Book, after mentioning about twenty Greek authors, who had written on Architecture and Mechanics, Vitruvius observes that very few books had been written on the Art by Romans; he names Fussitius as the first, afterward Terentius Varro and Publius Septimus, and he says that these were the only writers previous to his time; yet he allows that there must have been some great Architects among the ancient citizens of Rome, and he instances Cossutius, who was employed to complete the Temple of Jupiter Olympius, at Athens, in the reign of Antiochus, and Caius Mutius, who built, at Rome, the double Temple of Honour and Virtue, in the time of Marcellus. Of the Works of the above-mentioned authors, that of Vitruvius is the only one in existence; the others must have perished before the time of the revival of Learning in Italy.

In describing the Architectural works of the Greeks, we began with their Temples, because the construction of those edifices is more simple than that of any other species of building; and because a certain system had been adopted in the distribution of their parts before any rule was established for the Palaces of Princes, or the dwellings of private individuals. In an account of the Roman Architecture, it will be also proper to begin with the Temples of that people for the same reasons.

Forms of the Italian Temples.

The Italians occasionally erected Temples of a circular form, having the naos, or cella surrounded by columns, in a manner similar to that of the monopteral Temples of the Greeks; but the rectangular Temples are, in Italy, as in Greece, much more general than the others. They had the same denominations in both Countries with respect to the disposition of the columns, the number of columns in front, and the magnitude of the intercolumniations; but there are some differences in the proportion of the lengths to the breadths, and the Roman buildings have not always the same simplicity of plan as those of the Greeks.

No Tuscan Temples remain.

There is no Temple remaining to afford an idea of the style in which such edifices were constructed by the Etruscans; and from the brief description given by Vitruvius, we only learn that they were of a rectangular form, like those of the Greeks, with a portico in front, the columns of which were placed at a considerable distance asunder; that the shafts of the columns were plain and were supported on simple bases; that the walls and columns were of stone, and the entablature of timber.

A Temple at Cora, and another which is supposed to have formerly existed at Albano, both of which places are in the vicinity of Rome, have been considered as Etruscan works, but this is certainly a mistake; the Architecture of the former is evidently a modification or corruption of the Grecian Doric, and was no doubt executed by Greek colonists; and the fragments of a column and entablature which have been found at Albano no less evidently belonged to a Doric building executed in the time, and probably at a late period of the Empire. A Temple dedicated to Jupiter Latialis, is said to have been built at this place in the time of Tarquin the Proud, and both here, and at Tusculum, in the neighbourhood, are many substructions, which probably belonged to Tuscan or Latin buildings; but the Temple has entirely disappeared, and all those substructions seem to have been subsequently built upon, so that it is quite uncertain to what works the remains which have been discovered at these places are to be ascribed.

Temples Vesta a of the Si

Of the Roman circular Temples, there exist the remains of two, of ancient date, which deserve to be particularly mentioned. One of these is in Rome, and was dedicated to Vesta; the other is a Temple of Vesta, or of the Sibyl, and is situated at Tivoli. Their cells are cylindrical, and were supposed to have been covered at top by domes which rested on the walls, though they do not possess any feature which may render this fact certain. The Temple at Rome stands on three steps surrounding the building, and that at Tivoli on a circular basement, about five feet high, and bounded by a vertical wall. The exterior of each cella is surrounded by a colonnade of the Corinthian Order, and of a circular form; and Palladio says, that the lengths of the columns are equal to the diameter of the cella, agreeably to a rule given by Vitruvius in his IVth Book. The same Architect observes, that the columns are not planted vertically, but are inclined a little at top towards the wall of the cella; and this he supposes to have been intended to resist the horizontal thrust of the vault. But it has been since determined by measurement that the contrary is the case in the Temple at Rome; the axes of the columns being inclined outward at the top; and this inclination, which might be supposed to have arisen from the pressure of the vault towards the exterior, a pressure which the other construction was intended to prevent, is now believed to have been designedly given to counteract the effect of the general diminution of the upper part of the building, caused by the particular diminutions of the surrounding columns. In the Temple at Tivoli, the leaves of the capitals are cut into the substance of the vases, whereas they are generally executed in relief. Mr. Gwilt observes that this Temple, though not highly finished, is of a beautiful form.

The P theon.

But the circular Temples of Italy, which by some are supposed to have been adopted from the form of the Tower of the Winds, or the Monument of Lysicrates, are exhibited in the greatest perfection in the Pantheon at Rome. This remarkable building is generally supposed to have been built by Agrippa, about A. D. 14; though there seems reason to believe that the body of the Temple was erected during the Republic, and that only the portico was added or renewed by Agrippa. Its plan is a complete circle, whose interior diameter is 137½ feet; the wall is about 23 feet thick, with eight hemicylindrical cavities formed vertically in the thickness, at equal distances from each other, about the building, in order to save materials; and there are three semicircular, and four rectangular recesses, formed in the interior face of the wall, with two columns about 83 feet high in front of each, and a pilaster at each angle.

It is probable that, originally, all these seven recesses constituted as many semicircular-headed alcoves, open towards the interior of the building from top to bottom; though now the upper parts of some are concealed by the ornaments above the entablature of the columns and pilasters before-mentioned. The alcoves perhaps then contained altars, and, at present, they serve as chapels. All the lower part of the interior is of marble, and probably is as ancient as the time of Agrippa.

The cylindrical wall of the Temple, which is chiefly of brickwork, is 102 feet high, on the exterior, terminated above by a horizontal cornice, and divided into three parts, horizontally, by two other cornices, at the heights of 45 feet and 74 feet respectively; and within the thickness of the wall, in each of the two upper divisions, is formed a row of arches the interiors of which are filled up with horizontal courses of brickwork.

The curvature of the wall is interrupted in front by a rectangular projection 103 feet broad and advancing 20 feet from the circumference of the cylinder. This projection has a plane surface on the exterior, in which is the doorway, with a cylindrical recess on each side; it has four pilasters in front, and is terminated above by a pediment the horizontal cornice of which is on a level with the second of those on the cylindrical wall; the apex of the pediment is 20 feet above the base, so that the height of this member is about one-fifth of the whole length of the horizontal cornice. In front of this projection, and of equal breadth with it, is an octastyle portico, projecting 62 feet from the circumference of the circular part of the edifice; the columns have plain shafts, and are about 47 feet high, and there is a double row, each containing four columns, between those in front and the pilasters beforementioned. The portico is covered by a pediment similar to that on the wall of the building, and the horizontal cornice of the latter is cut by the sloping sides of the roof of the portico.

Above the columns and pilasters, in the interior of the building, is a horizontal entablature, over which is a podium surrounding the Temple; this formerly supported a row of small pilasters with rectangular recesses between them, and the whole was crowned by a second entablature, the top of which is on a level with the second exterior cornice. The pilasters, which seem to have been of later date than the columns below, are now removed, and a different arrangement of the ornaments has taken place. From the second entablature, as a circular base, 75 feet from the ground, springs the dome, which is of a hemispherical form, 137½ feet diameter, ornamented interiorly with five horizontal rows of sunk panels, whose sides have the appearance of inverted steps, and ending at top with a circular opening the diameter of which is 26 feet. Several horizontal courses of brickwork surround the dome at the top of the wall on the exterior, and seem as if intended to resist its lateral thrust. The whole Temple, inside and out, is of the Corinthian Order, and the foliage of the capitals resembles clusters of olive leaves. Formerly the pavement of the Temple was ascended by steps, but the ground has now risen so much on the exterior that it is necessary to descend in order to get within the building. A plan, elevation, and section of this Temple is given in pl. xii.

The height of the columns of the portico is 47.029 feet, and the lower diameter of the shaft is 4.797 feet; the architrave is divided into three faciæ, which are not exactly in vertical planes, but their upper extremities incline towards the building, and the height of the whole entablature is 10.217 feet, or $\frac{1}{4.6}$ of that of the column. The cornice has no dentels, and their place is occupied by a plain facia, but below the modillons is an echinus moulding sculptured with oves; the distances of the modillons from each other are equal to half a diameter of the column, and their breadths are equal to 0.2 diameter. See pl. xi. fig. 1.

In the interior of the Pantheon, the height of the columns is 34.674 feet, and the lower diameter is 3.642 feet. The shafts are fluted and the channels are filled with cablings, or reeds, as far as one-third of their height. The extremities of the modillons, and those sides of the lacunaria, or coffers, in the soffit of the corona, which, in a building formed by plane walls, would be parallel to the face of the wall, are here portions of circles the centres of which are in the axis of the building; and those sides of the modillons and coffers which would be perpendicular to the face, all tend to the same axis.

Temples of Bacchus

We may conclude our account of the circular Temples at Rome with a short description of those supposed to have been dedicated to Bacchus and Minerva Medica in the same city, though the changes they have undergone render it difficult to ascertain what was their primitive state. The former consists of a cylindrical wall, 89.36 feet diameter, raised upon twelve semicircular arches, springing from a double circular peristyle, the columns of which are coupled in the direction of the radii of the plan of the Temple, and the whole is crowned by a hemispherical brick dome, 65.6 feet high from the pavement. On the exterior of this circular peristyle is another cylindrical wall, enclosing a corridor 14.75 feet wide, which surrounds the colonnade; this corridor is crowned by a semicircular vault 32 feet high from the pavement, and between its roof and the base of the dome is a row of semicircular-headed windows in the cylindrical wall of the central part of the building. In front there has formerly been a portico, which is now destroyed.

and Minerva Medica.

The body of the Temple of Minerva Medica is of a cylindrical form on the exterior and 110 feet in diameter; but the interior of the wall is formed in ten plane vertical faces, in each of which is a semicircular recess open towards the centre of the building. The whole is covered by a hemispherical dome of brickwork, the vertex of which is 113 feet from the pavement. On each side of the body of the building there was formerly a semicircular wing covered by a vault in the form of a portion of a sphere, but these are now gone to ruin. At the entrance of the building is a rectangular vestibule, with four Corinthian columns, and two pilasters of the same Order in front. The whole vestibule is covered with a pediment roof.

It is observed by Mr. Forsyth that a custom has prevailed of considering every circular edifice containing alcoves, as part of a Roman Bath, and the three Temples last mentioned are among those to which that destination has been ascribed; the opinion may not be often well founded, but there is some probability that with respect to the Pantheon it may be correct. The Baths which, according to Dion, were executed by Agrippa, are supposed to have constituted an immense edifice of a rectangular form; and from the traces of walls which have been discovered at the back of the Pantheon, as well as from the great alcoves in the interior, this building is thought to have been a sort of vestibule connected with them on the side opposite the portico. Cameron's *Description of the Roman Baths.*

CHAPTER II.

The Religious Edifices of the Romans between the Times of Augustus and Constantine.

The generality of the Temples erected during and subsequently to the time of Augustus, in every part of the Roman Empire, were of rectangular forms; and though the plans of most of them have the simplicity of the Grecian models, yet there are some among them of a more complex character, and seeming to have been the prototypes of a style of building which, at a later day, became universal in the Religious Architecture of Europe.

Temple of Jupiter Tonans

At the foot of the Campidoglio, (the ancient Capitol of Rome,) formerly existed one of the Temples said to have been built by Augustus, and supposed to have been dedicated to Jupiter the Thunderer. The whole of it is now destroyed, except three columns, but by tracing the ruins, it is found to have been of a rectangular form, 115 feet long and 92 feet wide, measuring on a line circumscribing the columns. At that extremity of the cella which is opposite the pronaos was a hemispherical recess, open to the interior, and occupying nearly the whole breadth of the face. The Temple has been octastyle and dipteral, but the columns were not continued on the rear face, because that part was next to the rock, and nearly joined it. It seems that on this face was a very thick wall, and at a little distance behind it was an arcade, forming a facing to the rock of the Capitol, with half columns attached to the piers. The columns of the Temple are fluted, and of the Corinthian Order. It was about this building that, according to Suetonius, Augustus caused small bells to be hung, either for ornament, or that, by the sounds they emitted when agitated by the wind, birds might be deterred from settling upon the consecrated edifice.

The height of the columns is 47.082 feet, and the lower diameter is 4.598 feet, consequently the height is equal to 10.24 diameters. The base consists, besides the plinth, of two tori, between which are two scotiæ, with the fillets, and the scotiæ are separated from each other by a double astragal. The capital consists of two rows of leaves, the exterior surfaces of which have considerable obliquity to the axis of the column, and above these are the stems which curl under the abacus. The architrave is divided into three faciæ, all of which incline backward, and the mouldings which separate them are ornamented. A great rectangular panel, with ornamented borders, occupies nearly the whole of the architrave and frize over the front of the columns, for the purpose of containing an inscription, the faciæ of the architrave being interrupted abruptly to make room for it. The cornice contains a row of dentels between two quarter-circle mouldings, and over the upper of these is a row of modillons, which support the corona. The height of the entablature, not including the cymatium, is 9.514 feet, or $\frac{1}{49}$ of the height of the column.

Temple of Jupiter Stator.

Between the Campidoglio and the Palatine Hill are yet standing three beautiful Corinthian columns, which have usually been named the remains of a Temple dedicated to Jupiter Stator; but so little certainty is there of the truth of this denomination that the ruins are now supposed to have been part of the comitium in front of the Senate-house. Very little has been ascertained of the form of this Temple, if it has been one, but Palladio thinks it was peripteral and octastyle. The columns are 47.646 feet high, and the lower diameter is equal to 4.841 feet; consequently the height is equal to about 9.8 diameters. The architrave is divided into three faciæ, nearly equal to each other in breadth, and the exterior surface of the frize, as well as that of the lower facia of the architrave, is vertically over the circumference of the upper part of the shaft of the column: there are both dentels and modillons in the cornice. The height of the entablature, not including the epitithedas, is equal to 11.93 feet, or about one-quarter of the height of the column, and the under part, or soffit, of the corona has, formed in it, square coffers, or panels, ornamented with sculpture. (See figs. 2, 3, 4, pl. xi.)

Temple of Peace.

We are brought next to the remains of a Temple dedicated to Peace, which is remarkable for exhibiting a great deviation from the general simplicity of the Roman and Greek Temples. Its plan is rectangular, and a vestibule or porch was formed along the whole breadth of the building in front. The vestibule was covered by a vault, the height of which from the pavement was about 35 feet; in front were six semicircular-headed apertures serving as entrances, and, corresponding to these, were as many semicircular apertures in the front wall of the building. The length of the Temple on the exterior, not including the depth of the porch, is 294 feet; the depth of the porch is 30 feet, and the breadth of the Temple is 197 feet. The pavement was 10 feet above the ground, and there has been an ascent to it by steps in front of the vestibule.

The building may be considered as divided longitudinally into three parts nearly equal to each other. The central division, or as it would be now called, the nave, was a grand hall of a rectangular form, extending the whole length of the Temple, and equal in breadth to one-third of that of the Temple. This was covered by a vault, consisting of three groins, formed each by the intersection of two hemicylindrical vaults at right angles to each other. The height of the crown of the vaulting from the pavement must have been about 116 feet, and the interior surfaces of the groins show traces of having been ornamented with sunk panels. A hemicylindrical recess, 13½ feet deep, is formed in the wall at that end of the Temple which is opposite the entrance, and is covered by a half-dome, or quadrant of a sphere, the height of the vertex of which from the pavement is 71 feet. The front of the recess is open to the interior of the Temple, and the interior surface of its dome is ornamented with octagonal and square panels sunk in the masonry, with sides in the form of inverted steps.

The two lateral divisions of the Temple were each subdivided into three rectangular parts, nearly equal to each other, by two walls parallel to the breadth of the Temple; these parts were open towards the central division, and were covered above by hemicylindrical vaults springing from the walls just mentioned, and from the parallel extremities of the building. The height of the crown of these vaults from the pavement was 71 feet, and in each of the walls is an aperture of communication. The central part in each of the grand lateral divisions is terminated by a hemicylindrical recess, covered and ornamented like that at the extremity of the building; only one of these two recesses is now standing, and in its vertical wall are two tiers of small niches. Those parts of the side walls of the Temple which form the extremities of the other four parts into which the two lateral divisions are subdivided, are pierced with two tiers of apertures, like windows, with semicircular heads. Each of the four cross-walls terminated towards the central division of the Temple by a Corinthian column, from the entablature of which sprang the ribs of the groins which covered this part of the building. The columns are now destroyed, but parts of the entablatures and bases remain, which are sufficient to give indications of their character. The etchings of Rossini give an accurate idea of the present state of this Temple, and to them we refer the reader.

The roof being entirely destroyed, it is impossible to say how the building was covered on the exterior, but if the restoration given by Palladio were correct, it would appear that two sides of a sloping roof rose from the side walls of the building till they met the walls above the piers on each side of the central division; these were carried up higher than the walls of the two lateral divisions, and, according to that Architect, were terminated by a pediment roof.

The Temple was begun by the Emperor Claudius, and, after the conquest of Judea, it was finished by Vespasian, who deposited in it the spoils of the Temple at Jerusalem. It is said to have been destroyed by fire, or an earthquake, during the reign of Commodus, and, subsequently, to have been restored.

Of the sacred edifices, constructed according to the Ionic Order, which still exist at Rome, the Temple of Fortuna Virilis is the principal. This, which is nearly entire, is of the kind called prostyle, with four columns in front, and one on each side between these and the cella; the sides and angles of the latter are also ornamented with half-columns. The length of the columns is 27.348 feet; the lower diameter of the shaft is 3.109 feet; and this member is fluted with twenty-four semicircular channels having fillets between them. The base is of the Attic kind; and between the volutes in the capital, is a double echinus, of which the larger one is above the other, and immediately below the last is a small astragal and fillet. The architrave is divided into three faciæ, each of which inclines backward, in order, perhaps, to give a greater appearance of stability; the frize is ornamented with sculpture, and there are dentels in the cornice. The height of the entablature, including the cymatium, is 6.784 feet, or one-fourth of the column. (See figs. 5, 6, pl. x.)

This example is remarkable for having the middle of a dentel nearly corresponding with the axis of each of its columns, and all its similar ornaments placed with regularity vertically over each other in the different members of the entablature; circumstances which have not been attended to, perhaps, in any other edifice constructed by the Ancients.

The Temple of Concord is supposed, by some, to have been originally built in memory of the union between the Patricians and Plebeians, when the latter took refuge on the *Mons Sacer*; others think it was dedicated by Tiberius to consecrate the harmony between Augustus and Livia. Be this as it may, the inscription states that it had been destroyed by fire, and subsequently restored; and the bad taste of the restoration sufficiently indicates that it took place about the time of Constantine.

It appears to have been peripteral, with a hexastyle portico in front. The eight columns which remain are of red and white granite of different diameters; the bases are Attic, and all are without plinths, except those of the two angular columns. The capitals are deficient in elegance and badly cut; the architrave has been smoothed to unite it with the frize, and form a plain surface to contain the inscription; there are both modillons and dentels in the cornice, and the interior frize is sculptured.

The columns are 42.861 feet high, and the diameter of the shaft at bottom is 4.486 feet; consequently, the height of the columns is equal to about 9.5 diameters. The shafts of the columns are plain, and the inequality in their lengths is some proof that they have been taken from other edifices. Each capital contains eight volutes, formed diagonally with respect to the abacus; between the volutes is an echinus, with an astragal below it; under this comes a cima recta and fillet; and below these, that is, at the top of the shaft, is another astragal; the first three mouldings are sculptured, and the other plain. The architrave and frize are each equal to half a diameter in height, and the former has been divided into three faciæ. The height of the whole entablature is equal to 7.2 feet, or about one-sixth of that of the column; and above the cornice, over the intervals of the columns in front of the Temple, is a row of flat segmental arches, seemingly intended to relieve the weight of an incumbent structure from that part of the entablature.

Notices of sundry other Temples at Rome.

Of the remaining Temples at Rome, the following are the principal; we notice them only to show their general form, where this can be ascertained; for the proportions existing between the parts of the Orders employed do not differ materially from those in the examples which have been already exhibited.

Among the Temples built by Augustus at Rome there remain the ruins of one dedicated to Mars the Avenger. Its plan is rectangular; the whole length of the cella and pronaos together, including the thickness of the walls, was about 116 feet and the breadth about 73 feet. The Temple was peripteral and octastyle, with four columns between the antæ pilasters. The columns of the peristyle are of the Corinthian Order, and the intervals between them are equal to about a diameter and a half.

The Temple of Nerva Trajanus has a cella which is nearly square, but a portico without side walls projects in front. It is hexastyle, and there were two columns on each side, between the front wall of the cella and the front columns of the portico; all the columns are of Parian marble, and of the Corinthian Order, with fluted shafts. The pavement is raised from the ground and supported on arches; a method which, Vitruvius says, was practised in his time. The ascent to the pavement is by a flight of steps in front.

The Temple of Antoninus and Faustina was similar to the one last mentioned. Before this building, was a grand rectangular peristyle, consisting of coupled columns, which were surrounded by walls on three sides, the Temple occupying the fourth.

The building which has been supposed to be the Basilica of Antoninus, is now, with more reason, thought to have been a peripteral Temple. Its plan was rectangular, it had eight columns in front, and seven half-columns were attached to the interior face of the wall on each side of the edifice.

No traces now exist of the great pseudodipteral Temple of Jupiter on the Quirinal Hill, which was supposed by Palladio to have been of the kind called hypæthral; nor of an octastyle Temple of Mars, which he places between the Pantheon and column of Antoninus.

By the late excavations in the Forum of Rome, the following particulars have been ascertained respecting the grand double Temple, dedicated to Venus and

Rome, which formerly existed within the circuit of that magnificent place. It appears to have been a peripteral edifice, of a rectangular form, 351.5 feet long, and 166 feet wide between the centres of the extreme columns; and consisting of two square Temples joined together at their rear faces; in each of which was a hemicylindrical recess covered by a half dome. The building was decastyle, with twenty columns in flank and four columns between the antæ, both of the pronaos and posticus. To the pavement of the peristyle was an ascent by steps, and the whole was surrounded by a peribolus 525 feet long, and 318 feet wide, consisting of a double row of columns, twenty-six in front. The columns on the flanks of the peribolus were interrupted by a portico in the centre of each side, that is, opposite the place of junction of the two Temples; and there was an ascent to the platform of the peribolus by a magnificent flight of steps extending along the whole front. See the Work on the restoration of the Forum, by Caristie, and a Plate recently published from a design of Mr. C. H. Cockerell.

The Roman people must have beheld with pride the splendour of this Temple when in a perfect state; the perspective of the long files of columns forming the peribolus, blended with that of the more lofty columns about the richly ornamented building in the centre, must have produced an effect perhaps unrivalled in sublimity by any work in the ancient World.

We may conclude this account of the Temples in the city of Rome, by observing that in the Colonna Gardens have been found some fragments of an entablature which is believed to have belonged to the portico of a magnificent Temple, of the Corinthian Order, built by Nero. The Temple is supposed to have been dodecastyle, or to have had twelve columns in front; and from the measurements which have been made of the fragments we are enabled to determine the dimensions of the several members of the Order.

The height of the columns was 65.5 feet, and equal to about ten times the lower diameter. The architrave is divided into two faciæ, of which the separation and the crowning moulding are both sculptured, and the frize is filled with immense scrolls of the richest sculptured foliage, remarkable for its elegance, and for its approach to the purity of the Grecian style. The cornice is without dentels, and contains a row of modillons which are bounded every way by plane surfaces; these, as well as the modillon band, are divided into two faciæ of which the upper exceeds the lower in height and breadth; the corona is bold and plain, and the epitithedas is delicately sculptured. See fig. 5, pl. xi. The height of the entablature, not including the cymatium, is 14.184 feet, or $\frac{1}{4.6}$ of the height of the column; and the whole height of this gigantic Order must have been above 81 feet; the length of the portico was, probably, about 220, and the height of the vertex of the pediment from the pavement about 106 feet.

Within the limits of the Roman Empire innumerable Temples must have been erected previous to the time of Constantine, many of which were splendid edifices; but, of these, a few only have escaped the destroying hand of time: and, besides those in Rome, and the very ancient Temple at Tivoli, before-mentioned, the following are, perhaps, the most considerable.

Temple on the Clitumnus

On the Clitumnus, below Trevi, is a small prostyle Temple raised on a basement eight feet high, to which there is an ascent by steps in front, on each side of the centre, and leading to the entrances on the flanks of the porch. In front of the porch are four columns between two antæ pilasters which are detached from the walls; the pilasters are fluted vertically, as usual, but the columns are remarkable on account of two of them being fluted obliquely round the shaft, and the shafts of the other two being sculptured all over with leaves· sure proofs of a decline of good taste. Both columns and pilasters are of the Corinthian Order.

Temple Assisi,

At Assisi in Umbria is a Corinthian Temple with six columns in front, and two columns on each side of the portico between the wall of the cella and the front columns. The Temple is rectangular, and its length is nearly equal to twice its breadth; it is remarkable on account of the columns being placed on pedestals, a circumstance which has not been observed in any other ancient example. The ascent from the ground to the pavement of the Temple is by steps along the front of the building; upon the middle step are placed blocks which rise as high as the level of the pavement, and the bases of the pedestals stand on these blocks. The height of the pedestals is about equal to the breadth of an intercolumniation; that is, to about twice as much as a diameter of a column.

Templ Fortu Præne

But every building of Italy must, in grandeur of effect, when seen from a distance, have yielded to the Temple of Fortune at Præneste, about twenty-one miles from Rome. We have already given some account of this Temple in our *Miscellaneous Division*, (FORTUNE,) and we shall here add a few more peculiarly technical particulars. It was built on the upper part of a rock, one side of which was cut into four broad terraces supported by walls or arcades; and, from the little which is now visible, the following particulars have been ascertained. On approaching the rock, the spectator arrived at a flight of steps, 7 feet high from the ground, extending in length about 570 feet, and only broken by a rectangular projection from the centre; this led to a narrow landing-place from which, by a flight of steps at right angles to the former and commencing at the distance of 180 feet from the centre on each side, there was an ascent to another landing-place, 18 feet above the former, and supported, in front, by a row of semicircular arches on piers, of which many traces remain. In the centre of the second landing-place were steps leading to a third, which was 600 feet long, 22 feet above the first landing, and supported in front by a plain wall. Again, in the centre of this landing-place, were steps leading to the first grand terrace, which was, also, 600 feet long, and 80 feet broad. A few steps, extending the whole length of this terrace, led to the next, which is 570 feet long, and about the same breadth as the other. Near the centre of this were two quadrangular buildings, each 50 feet long, 33 feet broad, and 65 feet distant from each other. At the back of each of these Temples was a flight of steps at right angles to the former, leading to a third terrace, 270 feet long, 26 feet wide, and 36 feet above the first landing. On the right and left of the centre of this terrace was a high flight of steps parallel to the last and leading to the fourth, or upper terrace; this is 160 feet long, 70 feet wide, and 90 feet above the first landing; along its whole front and on each side was a colonnade. At the centre of the opposite face of the platform, appears to have been a semicircular colonnade, 43 feet diameter, which might have been part of a Theatre; and on this, which was the principal terrace, was probably the great Temple.

Similar systems of buildings exist in places once occupied by the Greek colonists in Asia Minor.

These extensive terraces, rising gradually above each other in a pyramidal form, to the height of above 100 feet from the plain, and adorned with splendid colonnades, must have presented an imposing spectacle; which, aided by the veneration inspired by the Oracle, whose seat was at this place, must, also, while the superstitions of heathen Rome prevailed, have rendered Præneste one of the most interesting spots in a land where almost every object, natural or artificial, could excite in the mind of the observer admiration or devotion.

The five Temples last mentioned are within the limits of Italy; and there now only remain to be described a few of the principal Roman Temples the ruins of which still exist in the Provinces of the Empire.

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At Nismes, in Provence, are the remains of two buildings which are generally believed to have been Temples, though one of them has been supposed to be a Basilica, or Court of Justice. The latter, which goes by the name of the *Maison Quarrée*, is of the Corinthian Order, and stands on a stereobata, 10 feet 5 inches high, with steps along the whole front; it is hexastyle, with two columns on each side between the cella and the front columns, and there are half-columns placed at intervals against the walls on the sides and rear of the building. Above the basement are two courses like steps along the side-walls, and the plinths of the columns rest upon the upper of these courses.

The other is a rectangular Temple, on the exterior of which are no columns but, instead of them, a wall surrounds the cella at the distance of about seven feet from it, and encloses a passage. There is a doorway leading into the passage on each side of the building, but the door of the Temple was in the interior wall in front, so that the cella of the Temple must have been completely dark; and, hence, Palladio infers that it must have been dedicated to the Infernal Gods; others suppose it to have been a Temple of Diana. There are recesses all round the interior of the cella, in which, perhaps, were statues, and there are columns on pedestals between the recesses. From the entablature, above the tops of these columns, sprang the principal arches which, like semicircular ribs, extended across the Temple, and from one of these arches to another were placed slabs of stone, longitudinally, which formed the vaulted roof, but this is now fallen down. At the extremity of the cella opposite the doorway, the breadth of the floor is divided into three equal parts, forming divisions which are nearly square; the middle space had pilasters at the angles, and is on a level with the floor of the Temple; the two side-spaces are raised as high as the pedestals of the columns and pilasters; and the ascents to the two platforms are by steps formed in the thickness of the adjoining wall of the cella, through which the entrances are made from the passages round the building. The capitals of the columns in this Temple have two rows of leaves, above which is a sort of fluting, and, over all, a circumference of oves; but they are remarkable for having no volutes. The edifice is thought to have been a Roman work executed at a late period of the Empire.

The conquerors of mankind have, almost always, caused the style of Architecture practised in their own Nation to be adopted, and even to supersede that which originally prevailed in the Countries they subdued. Thus we find the rude majesty of the Egyptian edifices was exchanged, in the Northern part of that Country, for the lighter Grecian and Roman styles, after the invasions of Alexander and Cæsar; the Doric and Ionic Orders, which were almost exclusively employed by the ancient Greeks, were supplanted by the Corinthian, after the Roman conquest. Thus, also, whatever style prevailed in Syria in the earliest times, whether the Egyptian or some modification of it, nothing now exists of such a style in that Country; and the Architectural monuments which Time and the Barbarians have partly spared, were, evidently, erected during the existence of the Roman power in that part of the World.

Temple at Balbec.

This is the case with the Temple of the Sun at Heliopolis or Balbec, in Syria, a city once of great importance and situated in the neighbourhood of Tyre. According to the testimony of the Historian, John of Antioch, this Temple was built by Antoninus Pius, probably to replace a more ancient one erected by the Greeks or Syrians; and from the descriptions given by Messrs. Dawkins and Wood, who visited Balbec in 1751, we are enabled to obtain a just idea of these interesting remains, which had been so long unknown to the people of Europe. The Temple itself was of a rectangular form, and occupied the Western extremity of a great quadrangular enclosure, the sides of which were parallel to those of the Temple. On the opposite side of the rectangle was a hexagonal court serving as a sort of vestibule, and a grand portico formed the Eastern extremity of the whole.

The Temple was surrounded by two rows of Corinthian columns; its length, from West to East, was 268 feet, and its breadth, from North to South, was 146 feet, measured on a line circumscribing the exterior columns, and the entrance was on the Eastern side. The portico had ten columns in front, and there were nineteen in the exterior row along each flank. No more than six of these columns were standing when the gentlemen above-mentioned were on the spot; their height is 58 feet, their diameter 6.917 feet, and the height of the entablature about 13 feet. The intercolumniations are equal to 14 feet, and the distance of the columns from the walls is the same. The shafts are plain; each consists of three cylindrical blocks connected together by iron-plugs about one foot diameter, and the bases are of the Attic kind. The entablature is extremely enriched; in its cornice are both dentels and modillons, and a pediment roof probably crowned the whole. The colonnade of the Temple was surrounded by a terrace 30 feet high, above the level of the neighbouring ground, and supported on the exterior by a sloping revetment wall.

The pavement of the portico of this Temple is ascended by thirty steps, and the front wall within the portico is enriched with sculpture; the jambs of the portal are of marble richly sculptured, and the soffit of its architrave is ornamented with a great eagle, in bas relief, with extended wings and holding a caduceus. The interior of the Temple is divided into three parts longitudinally, by two rows of fluted Corinthian columns standing on pedestals, and supporting an entablature. The walls are ornamented with pilasters corresponding to the columns, and the intervals are occupied by niches with semicircular heads; the bottoms of the niches are on a level with the bases of the columns, and above these niches are others crowned by pediments. Towards the Western extremity of the central division is an ascent by thirteen steps to a hemicylindrical recess forming a sort of sanctuary, the entrance to which is between two great pilasters, and the interior is ornamented with festoons, flowers, birds, Neptunes and Tritons. The pavement of the Temple is supported by great vaults which, perhaps, covered a subterranean Temple.

The great quadrangle is in length about 360 feet, and breadth about 350 feet, and the Temple is situated on the middle of the Western side; on the three other sides are quadrangular recesses, or apartments, 60 feet long and 22 feet broad; these are open towards the centre of the area, and, in front of each, were four columns supporting the roof. Between these, on the Northern and Southern sides of the quadrangle, there are semicircular recesses, each 32 feet in diameter, with two large columns in the open sides next to the court.

The hexagonal court, before-mentioned, on the Eastern side of this peribolus, is itself enclosed within a quadrangular area 146 feet broad, and having its length equal to the breadth of the great quadrangle, of which this appears to be a continuation. The hexagonal court is also surrounded by recesses, or apartments, contiguous to the interior faces of the walls, and similar to those in the great quadrangle; they had columns in front, and their walls were adorned with niches or tabernacles.

On the Eastern side of the hexagonal court is the grand portico, which is 180 feet long, 40 feet deep, and elevated 24 feet above the ground in front, from which there is an ascent to the pavement by steps of the same length as the portico itself. The latter is flanked at each end by a tower 38 feet long, and 31 feet wide, ornamented by pilasters attached to the exterior faces of the walls; the towers are open towards the interior of the portico, and in the aperture of each were two Corinthian pilasters. The front of the portico was formed by twelve columns of the Corinthian Order, with plain shafts and Attic bases. The diameters of the columns at bottom are 4 feet 3 inches, and their height, including the entablature, was 52 feet. The architrave is divided into faciæ, of which the upper one is enriched with sculpture; the frize is plain, and there are both dentels and modillons in the cornice. Over the portico was an Attic Order, 10 feet high, with pilasters above each column. The bases of the columns rest upon pedestals, 3 feet 6 inches high, the faces of which project from that of a podium, of the same height, and extending the whole length of the Eastern face of the wall enclosing the quadrangle. Under the portico are recesses or tabernacles, in two rows, with circular and triangular pediments, of which some are complete, and others interrupted at the vertex. In the wall under the portico are three doorways, of which the middle one is 34 feet high, and 17 feet wide; these lead into the hexagonal court, on the opposite side of which are three similar doorways forming the entrances to the great quadrangle.

On the Southern side of the great Temple is a smaller one, of later construction, with a vaulted roof; this Temple is of a rectangular form, peripteral and octastyle, with a double row of columns in front, and thirteen columns on each flank; all are of the Corinthian Order, with shafts 44 feet high, and 4 feet 11 inches diameter. The roof under the colonnade has been sculptured in tablets of hexagonal, rhomboidal, and triangular forms, within which are represented Jupiter, Leda, and Diana; also some busts, probably of Emperors and Empresses. On each side of the doorway in the middle of the wall is a staircase, and at the interior angles of the cella there are portions of two columns the shafts of which are joined together. Along the wall in the interior of the cella there is a row of half-columns, 4 feet diameter, attached to the faces of a number of square piers projecting from the wall, and distant from each other 6 feet 7 inches. The columns stand on pedestals 11 feet high, and their height, including the entablature, is 49 feet; the latter is broken over the columns, and, above it, springs the vaulted roof. Between the columns are two tiers of recesses, of which those in the lower tier are terminated by semicircular, and those in the upper tier by pediment heads. At the Western extremity of the cella is a rectangular space, like a sanctuary, on a higher level than the pavement, from which there is an ascent to it by steps; in front are two piers with a half-column attached to the face of each.

Near this edifice are the remains of a third Temple with a circular cella, 32 feet diameter, standing upon a high stereobata, and appearing to have been crowned by a hemispherical cupola. The cella is ornamented with Corinthian pilasters attached to the walls, between every two of which are semicircular-headed niches. One face of the stereobata is rectilinear, and the remainder is cut in five faces in the form of rentrant arcs of circles. On the rectilinear front are four columns, each 39 feet high and 3 feet diameter, which constitute a façade 50 feet long on that side; and over each of the salient points of the basement is placed one column, so that the cella of the Temple appears to be surrounded by columns, all of which are of the Corinthian Order. The columns support a horizontal entablature, which forms rentrant arcs of circles between the columns, like the basement. The interior of the cella is octangular, and surrounded by insulated columns, between every two of which are niches; and a general entablature crowns the whole.

Temple, Palmyra

In the middle of the Desert, between Balbec and the Euphrates, lie the remains of the ancient City of Palmyra, which, by some, has been thought to be the Tadmor in the Wilderness, built by Solomon. Innumerable ruins now cover the ground on which the city stood; but nothing has been observed among them which can justify our assigning them an antiquity higher than the time of the Roman Empire; and it is probable that the edifices to which they belonged, were raised about the same time as those of Balbec.

The principal object is a Temple of the Sun, which stood in the centre of a rectangular peribolus, nearly square, and about 740 feet long in each direction. The walls forming the peribolus were 59 feet high, and were raised upon a continued podium, the height of which from the ground was 16 feet; both on the exterior and interior faces of the walls was a row of attached Corinthian pilasters, and an entablature crowned the whole. On the Western side of the enclosure was a portico, 138 feet long; its pavement was on a level with the top of the podium, and the ascent was by steps extending the whole length of the portico. The front of the latter consisted of ten Corinthian columns with Attic bases; of these, the three extreme on each side are single, and the others are coupled together in two pairs, one on each side of the centre. The line of columns projected 49 feet from the face of the wall, and was crowned by a pediment. The architrave was divided into several faciæ; the front of the frize swelled in an elliptical curve; and there were both dentels and modillons in the cornice. The portico was continued through the wall, and formed another on the interior. Within the enclosure, and parallel to each wall, were two rows of columns, except on the Western side, where the portico stood, and here there was but one row. The columns on this side were 48 feet 7 inches from the interior face of the wall, and 8 feet 3 inches from each other; but, on the other sides, one row was 19 feet from the face of the wall, and the other at the same distance from the first. Altogether, there were two hundred and eighty-eight pillars surrounding the court, with a highly enriched entablature above them. The shafts of the interior columns were all plain, and on each was fixed a bracket to support a vase or a statue.

The Temple within the enclosure was quadrangular, the length of its cella, from North to South, was 133 feet 4 inches, and its breadth, from East to West, 47 feet. The walls of the cella were terminated by antæ pilasters; between which, at each extremity of the building, were two Ionic half-columns at equal distances from each other and from the ends. The Temple was raised upon a platform, which was ascended by steps surrounding it; it was peripteral, with eight columns in front and fifteen on each flank, and the distances between the faces of the pilasters on the wall and the nearest sides of the columns are about 22½ feet. The columns stand on plinths 1 foot 8 inches high, and the height of the column and entablature, including the plinth, is 64 feet. The shafts are fluted, and the capitals seem to have been ornamented with metallic leaves and volutes, fixed to the vases; the entablature is filled with sculpture, and there are both dentels and modillons in the cornice. The principal entrance faces the West, in one of the long sides of the Temple; where there is a doorway, 33 feet high and 15 feet wide, between two clustered columns which form part of the peristyle of the Temple; and there are four windows on each side of the cella, rather narrower at top than at bottom. In the interior, at each extremity of the ceiling, are panels of square, octagonal, and rhomboidal figures, each having a flower in the centre; and, about the circumference of a circle, in one division, are the signs of the Zodiac.

About 1200 feet to the North-West of this Temple commences a quadruple row of columns, about 82 feet broad, and supposed to extend to the distance of 4000 feet. At the entrance of this colonnade is a gateway, resembling a triumphal arch, having three passages, and crowned by a pediment; it stands obliquely to the lines of columns, and is adorned with Corinthian pilasters, whose faces are panelled and enriched with sculpture. Near this is a Temple, the cella of which is square with a portico consisting of four Corinthian columns in front, and one on each side between the front row and the antæ; and there are half-columns attached to the exterior on each face. On the shafts of the columns in front of the portico are brackets for the support of statues, and the frize is enriched with festoons.

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polis.

In various parts of Syria are remains of Roman Architecture, similar, in style, to that of Balbec and Palmyra. One of the cities of the Decapolis, now called Djerash, situated on the Eastern side of the Jordan, in about 32° 20′ North latitude, and which is thought by Mr. Burckhardt to have been the ancient Gerasa, contains many interesting objects which have been attentively examined by Mr. Barry, who lately visited this place in the course of his extensive travels in the East. We are informed, by this gentleman, that the city consisted of two long streets crossing each other at right angles, and, at the extremity of one, is a great elliptical area, which, as well as the sides of the streets, is adorned with magnificent columns; but, as accurate delineations of these ruins have not yet been published, we content ourselves with quoting the general description given by Mr. Burckhardt, which will convey some idea of their character.

This enterprising traveller states that the first object which strikes the attention, on coming from Souf, after passing the wall surrounding Djerash, is a Temple in the form of an oblong square, 25 paces long and 18 broad, executed in a style of Architecture which belongs to the best period of the Corinthian Order, and superior to every building of the kind, except the Temple of the Sun at Palmyra. The ruin stands on an artificial terrace, five or six feet above the ground, and two rows of columns, containing six in each, adorn the front; it occupies the interior of a peribolus formed by a double colonnade, which is remarkable in having the corner columns composed of two shafts joined together in such a manner that, on the plan, the double column resembles a heart.

Proceeding Westward from this Temple, through the ruins of private habitations, at two hundred yards distant from it, are the remains of a small Temple, of which three Corinthian columns alone exist. The streets are, partly, paved, and on each side are colonnades, which present some peculiarities. In certain places a tall column stands near a short one, the entablature of the latter resting on a bracket placed against the shaft of the former, which must have given to the façade the appearance of patchwork. Behind the columns are several low apartments covered with vaulted roofs. Near the extremity of the long street are the remains of an Aqueduct; hence the ground rises, and on the top of the hill is a beautiful Temple with a Corinthian peristyle. Near this is a large Theatre. Similar ruins are observed at Omkeiss, or Gamala, and at Amman, or Philadelphia.

The Provinces of Asia Minor have been lately traversed in different directions by English Missionaries, and from their notices we learn that there are to be seen in them many interesting remains of Roman, or of the later Grecian Architecture, capable of rewarding the difficulties and dangers to which artists would be exposed in exploring them.

We have now described the principal Religious edifices that were erected within the limits of the Roman Empire, previously to the Age of Constantine; and we may conclude this Chapter by stating some general rules, which have been given by Vitruvius, concerning the proportions employed in, or recommended for this species of building.

Proportions
of circular
Temples.

We have seen that circular Temples were frequently constructed by the Romans, and that they possess an important feature which is not to be found in any Grecian work; *viz.* the vaulted roof, of a hemispherical form. This mode of building seems to indicate a considerable acquaintance with the laws of mechanical action; but by whom it was invented it will be for ever impossible to ascertain. Vitruvius prescribes that, in monopteral Temples, the pavement should be raised on a stereobata, at a height, above the ground, equal to one-third of their diameter. But when the circular range of columns encloses a cella, the basement should be surrounded by steps; the space between the columns and the wall should be equal to one-fifth of the whole diameter of the Temple, and the height of the columns above the basement should be equal to the interior diameter of the cella. (Book iv. ch. vii.)

Proportions of rectangular Temples.

For the plan of those which he calls Tuscan Temples, Vitruvius gives the following proportions. The breadth is equal to five-sixths of the whole length; half this length is occupied by the cella, which is divided into three parts by walls parallel to the length; the other half is taken up by the pronaos, which has four columns in front, with, perhaps, another row of columns between these and the front of the cella. Such Temples, constructed of timber, probably existed, in Italy, in his time, but not a single example of this kind remains at present.

With respect to rectangular Temples in general, he states that their breadth should be equal to half their length; five-eighths of the whole length should be occupied by the length of the cella, and the side walls of the latter should extend, beyond the front wall, as much as the remaining three-eighths, to form a pronaos; these walls should be terminated by antæ pilasters. If the cella is more than 20 feet wide, two columns might be placed between the antæ, to separate the pronaos from the pteromata, or walks about the Temple. Between the antæ and the two columns just mentioned, he supposes there is raised a *pluteus*, or fence, of marble; he does not say of what height, but probably it was a low wall or species of balustrade. If the breadth is more than 40 feet, he directs that another row of columns should be placed between the front of the cella, and the row between the antæ; and these, though they have the same height as the others, are to be made less thick, it being supposed that, in a space enclosed by three walls, they will appear thicker than the outside columns; or, rather, that the latter will appear more slender than the others, for reasons which have been before stated.

By making the length of a Temple equal to double its breadth, as above prescribed, it will be found that, in peripteral Temples, (supposing the length and breadth to be limited by the centres of the extreme columns in front and flank,) the number of columns in the flank of the Temple should be one less than double the number in front, the extent of the intercolumniations being all equal, and including the extreme columns in reckoning the number both in front and flank. This disposition of the columns is different from that which is supposed to have been affected by the Greeks, as has been shown, and has the advantage of greater simplicity. Among the Romans, it seems to have been generally attended to, when a peripteral Temple was constructed of considerable magnitude, like those of the Sun, at Palmyra and Balbec; but the proportions of the cellæ were very various; far from being conformable to those prescribed by Vitruvius, they are frequently square, or nearly so, as in the Temple of Fortuna Virilis at Rome; and, often, the extremities of the Temples were without pteromata or wing-walls, instead of which, there were merely columns on each side of the pronaos, as in the Temples of Fortuna Virilis and of Concord at Rome.

Doorways of the Roman Temples.

Vitruvius, in the VIth Chapter of the IVth Book, states the forms of the doorways of Temples to be of three different kinds; the Doric, the Ionic, and the Attic. In all three, the members about the aperture have a correspondence with the parts of an entire Temple; thus the jambs, or, as he calls them, the *antepagmenta*, correspond with the columns; the lintel, or *supercilium*, corresponds with the architrave; above the supercilium is a kind of frize, which he calls *hyperthyrum*, and, over this, a *corona*, or cornice.

According to the text of Vitruvius, the height of the aperture of the Doric doorway is to be four-sevenths of the height of the soffit, or ceiling of the pronaos, from the pavement of the Temple; but, as he had before directed the top of the cornice of the doorway to be on a level with the tops of the capitals of the columns in front, this makes the space above the aperture too high, and Newton, his translator, proposes to make the height of the aperture equal to five-sevenths of that of the soffit, as is practised in the Temples at Cora and Tivoli. The breadth of the aperture at bottom is made equal to eleven-twenty-fourths of its height, and the breadth at top is less than that at bottom by one-third, one-fourth, or one-eighth of the breadth of the antepagmentum, at bottom, according as the height of the doorway does not exceed 16 feet, 25 feet, or 30 feet, respectively. Above this last height, Vitruvius proposes the doorway to be of equal breadth at top and bottom; and, in these circumstances, there is some analogy with the diminutions of columns.

He makes the breadths of the antepagmenta, at bottom, equal to one-twelfth of the height of the aperture, and to be diminished, at top, as much as one-fourteenth of the breadth at bottom. The heights of the supercilium, the hyperthyrum, and, perhaps, the cornice, are each to be equal to the breadth of the antepagmentum, at top, not including the cymatium, or moulding on its exterior; the projection of the corona is equal to the same. The supercilium extends, right and left, beyond the exterior of the antepagmenta, at top, so much as to make the extremities stand vertically over the foot of those members, and the cymatium, or exterior moulding, bends round this projection. From this description it will appear that the form of the doorway, with its vertical and horizontal architraves, very much resembles that of the window in the Temple of Minerva Polias at Athens.

The Attic doorway is like the Doric, except that the antepagmenta and supercilium are each divided into two faciæ, of which the exterior projects a little more forward than the interior; and the breadth of the latter is, everywhere, equal to five-sevenths of the breadth of the whole antepagmentum within the cymatium.

In the Ionic doorway, the height of the aperture is found as in the Doric; its breadth at bottom is equal to three-fifths of its height, and the contraction at the top is the same as before. The breadth of the antepagmentum is one-fourteenth of the height of the aperture, and that of the cymatium is one-sixth of the former: the antepagmentum is divided into three faciæ, whose breadths are respectively one-fourth, one-third, and five-twelfths of that of the entire member. The corona over the door is supported, at each extremity, by a console, which Vitruvius calls *ancon* or *prothyris*.

The members about the windows of the Roman Temples were formed in a similar way.

CHAPTER III.

The Dwelling-houses of the Romans.

We turn our attention next to the domestic structures of the Romans, which we purpose to describe from itec- re.

such remains of them as are yet in existence, and from the short, and, generally, obscure accounts given by Vitruvius.

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The Consul Pliny, in epistles to two of his friends, Apollonius and Gallus, describes, at some length, the interior arrangement of two Villas, the one in Tuscany, the other, which was the place of his winter residence, at Laurentinum; and the description of the latter, which is in greater detail than that of the other, may serve to convey some notion of the style of the houses occupied by the wealthy Senators of Rome, in the most brilliant period of the city. No remains of this Villa are now to be seen, and there is not sufficient precision in the account to allow a plan of it to be given; it may, however, be worth while to exhibit an outline of that account, which, with a faint idea of the disposition of the apartments, will afford an opportunity to introduce the names by which they were designated.

The entrance, he says, was by a plain *atrium*, or court, which led to a circular portico, or colonnade, surrounding a pleasant area; the colonnade was roofed and had windows of lapis specularis, which excluded the rain and rendered it a convenient retreat in bad weather. After passing this colonnade there was a *cavedium*, or open square, and, beyond this, a handsome *triclinium*, or state dining-room, which looked towards the sea on three sides, through folding-doors or windows. On the left of the passage leading to this *triclinium* were two *cubiculi*, either bed-chambers or saloons, of which one was smaller than the other, and had windows looking East and West. The angle, on the exterior of the building, between the *triclinium* and these *cubiculi*, formed a space screened from the cold winds, and serving as a *gymnasium*, or place of exercise, for the family in winter. Near this was a circular building, the windows of which, he says, admitted the sun during the whole day; it was, therefore, probably elevated above the ground floor; this served as a small *bibliotheca*, or library, and close to it was a dormitory, which was heated by a stove under, or near it. The remainder of this wing of the building was appropriated to slaves and freedmen. On the right of the passage leading to the great *triclinium* was an elegant apartment, and, beyond that, a larger one, serving as a *cœnatio*, or common supper-room; after this came a bed-chamber and *procoiton*, or anteroom, and separated from these by a wall, were two other rooms of the same kind. From these, there was an entrance to a cold-bath, in which were two *baptisteria*, or bathing-places, large enough to swim in; and, joining it, were the *unctuarium*, or anointing-room; the *hypocaustum*, or vapour-bath, and the *propigneon*, or furnace, with two small sitting-rooms. Adjoining these, was the *calida piscina*, or warm bath, from which the bathers had a view of the sea. Near this, there were two turrets, or summer-houses, one of which contained two *diætæ*, or suites of apartments, one on the ground, and another on the upper floor; from the latter there was a beautiful prospect of the sea and the neighbouring villas; the other turret contained a *triclinium*, below, and an apartment above, and, near this, were sundry *apothecæ*, or store-rooms, and a gallery of curiosities.

In the garden was a *cœnatio*, or banqueting-room, with two other apartments behind, and a gallery or colonnade, with windows on each side, looking, on one hand, towards the sea, and, on the other, towards the garden; before this was a *xystus*, or terrace for walking. At one end of this terrace stood a detached building, in which was a *heliocaminus*, or an apartment warmed by the sun, on one side of which was a recess containing a couch, and adjoining this, a bed-room heated by a small stove. An *andron*, or open space, between the walls of the bed-room and that of the garden, prevented the inmates of these chambers from being disturbed by any noise made by the servants.

Houses of Pompeii.

The ruins of the town of Pompeii, which were discovered in the middle of the XVIIIth century, after remaining buried in the ashes from Vesuvius about 1700 years, afford considerable knowledge of the interior disposition of the dwelling-houses of ancient Italy. In this town they are generally small, as may be expected in a city of the third degree in the Empire; they appear to consist but of one floor, though there may have been rooms above those which are now visible; and, next to the street, they have shops which often do not communicate with the houses to which they belong; the shops are open from wall to wall, except a low parapet in front; the doorway is narrow, and a stone-slab in the interior served as a counter. Many of the houses have peristyles, surrounding open courts; one of these is described as having five chambers on each of the sides, on the right and left of the entrance, and three on the side opposite the entrance; these are paved with mosaic, and the walls are painted: one of the chambers seems to have been a sleeping-room, as there is a recess formed in the wall, which might have contained a bed; this room is 8¾ feet long, and 7 feet wide, with a vaulted ceiling; the walls are covered with stucco, and painted red; but it is remarkable that, neither at this place, nor at Herculaneum, have any chimneys been discovered, though it is evident from passages in ancient authors, that the Romans had such. In these towns, instead of chimneys, there seem to have been *hypocausta*, or stoves, with pipes for conveying the heat to the different apartments. The *triclinia*, or dining-rooms, have but little light from the windows; whence we may conclude that these apartments were only occupied at the time of the principal meal, which took place in the evening by the light of lamps.

At a little distance from the town is a sort of villa, consisting of two divisions, in one of which the apartments are adorned with paintings; in the other is a court, 94 feet square, with a covered gallery on two sides, supported on square piers; the other two sides were occupied by trees, of which some of the trunks and branches lately remained. Beyond this is an open portico supported by six columns. The galleries and apartments are remarkable for their tesselated pavements, arabesque walls, and Doric columns, the flutings of which have been filled with a painted coat of plaster. On some of the walls have been scratched ill-shaped horses, ill-spelled names, and coarse jests; circumstances which have led to an opinion that these buildings have been originally barracks; but Mr. Forsyth considers them to have constituted the Governor's *prætorium*.

From what has been published of the buildings at Herculaneum, it appears that the rooms are small in dimensions, and contain some specimens of rich painting. But Mr. Forsyth states of the latter, "that every extravagance condemned by Vitruvius enters into it; the human and brute forms are fantastically represented, the landscapes are but the caperings of a sportive genius, and the Architecture is as bad as that of the Chinese."

The Villa of Hadrian.

The Villa of Hadrian, at Tivoli, seems to have contained specimens of all the different buildings which were ever constructed by the Romans for use or pleasure; it is now in ruins, but among them can be traced a Temple, two semicircular Theatres, a Palæstra surrounded by arcades, a Bath, a Circus, and a Naumachia, which may have been filled from the waters of the Anio, or Teverone; a long wall pierced by arches, and at its extremity a small tower, the circumference of which is formed of three concave and three convex arcs, placed alternately. This immense edifice had but a short existence; for eighty years after it was finished, Caracalla took away some of the statues which adorned it, and soon afterward it was totally abandoned.

Palace of Dioclesian.

We may conclude this account of the Roman dwellings by a short notice of the Palace of Dioclesian, at Spalatro, which was erected by that Prince in the beginning of the IVth century, and the plan or disposition of which is probably similar to that of the Palatial buildings of former Emperors. It is described by Mr. Adam as an assemblage of buildings within an enclosure nearly rectangular, and the sides of which nearly faced the four cardinal points of the horizon; its length, from North to South, is 698 feet, and from East to West, 592 feet; six octangular and ten square towers flank the wall; but they seem to have been intended rather for ornament than defence. The interior is divided into three principal parts by two streets, each of which is about 36 feet wide; one is directed from East to West, through the centre of the building, and is terminated by a gate formed in the exterior walls on each side; the other is at right angles to this, and leads from a gate in the middle of the Northern wall to the centre of the Palace. Both streets are bounded on each side by an arcade, 13 feet wide. The Northern gateway is crowned by a horizontal lintel, consisting of small stones with oblique joints which are broken horizontally in the middle; above this is a semicircular-headed arch, and on each side a small hemicylindrical niche, with Corinthian pilasters; over the whole is a row of seven segmental arches, springing from Corinthian columns which rest on consoles projecting from the wall, and are ornamented with zig-zag mouldings. Above the capital of each column is a plain block of stone, between which and the foot of the arches is a horizontal band adorned with sculpture; the upper mouldings of the archivolts do not bear on the supports of the foot of the arch, but come to a point a little above them.

In the middle of the Palace, and on the Southern side of that street which is directed from East to West, is a peristyle of Corinthian columns, from the capitals of which spring semicircular arches; above these is an entablature, with a frize, the exterior of which is formed like a portion of the convex surface of a cylinder, having its axis horizontal, and there are modillons in the cornice. On the Southern side of the peristyle is a flight of steps leading to a *vestibulum*, with a portico in front, consisting of four columns of the Corinthian Order, the tops of whose capitals are on a level with the tops of the arches on each side of the peristyle; above these columns is a pediment, the horizontal entablature of which is broken, and forms an arch over the interval of the two middle columns. The *vestibulum* is of a circular form, and seems to have been lighted from the roof. A doorway on the Southern side of this leads to the atrium, a large rectangular hall divided into three parts, by two rows of columns parallel to its length; on each side of the door into the atrium is a small room, one of which Mr. Adam supposes to have been a porter's lodge, and the other the *tablinum*, or repository for the archives and records of the family. On the Southern side of the atrium is a doorway leading to a *crypto-porticus*, an immense gallery, 22 feet wide, extending quite along the Southern side of the building, and commanding an extensive view of the harbour and of the Adriatic; it was probably adorned with paintings and statues, the beauties of which, as Gibbon observes, added to those of the prospect, must have caused it to afford a delightful promenade. The Southern side of this gallery, and of the whole building, is formed by an arcade, with columns standing on consoles projecting before the exterior face of the wall; the capitals of the columns are plain bell-shaped vases, and over the arches is a horizontal entablature which is broken so as to project over the columns; it consists of an architrave and cornice, of which the latter is supported by modillons.

On each side of the *atrium* is a passage, the mesaula of the Greeks, so called from its situation between the halls. These lead to the great apartments of the Palace, and beyond the latter are the rooms for bathing.

In an area Westward of the *atrium* is a rectangular Temple which was dedicated to Æsculapius; fifteen steps afforded an ascent to its pavement, beneath which are vaults of great strength, and the roof is of a hemicylindrical form, adorned with sunk panels of beautiful workmanship. In the cornice of the doorway are modillons, the soffits of which are sculptured to represent birds, and men whose legs end in tails like those of fish.

On the other side of the *atrium* is an octagonal Temple, dedicated to Jupiter; to this, also, there is an ascent by steps, and it is roofed by a hemispherical dome of bricks. Round the inside of this Temple are two Orders of columns, placed one above another, and standing a little beyond the face of the wall; the lower Order is Corinthian, and the other Composite; the columns have no bases, are only seven diameters high, and behind them are pilasters attached to the wall. The entablature is broken, so as to project over each column, and its frize, which is convex outwards, is sculptured with foliage. Over the pilasters spring slender brick arches in the concave surface of the wall, and their interiors are filled up with horizontal courses of the same material. The dome springs from the foot of these arches, and the bricks composing it are disposed in a sort of fanwork, which assumes the appearance, and may have given the first idea, of pendentives. Below the entablature, the interior of the Temple is surrounded by bas reliefs, and in the ornaments about the doorway are sculptured the heads of men and horses in the centres of the scrolls of foliage.

In the North-Eastern and North-Western quarters of the Palace are two piles of building, each two stories high, but in a ruinous condition: Mr. Adam supposes them to have contained apartments for women, or for the various attendants on the Court. Along the interior face of the Northern, Eastern, and Western sides of the Palace are vaults, which may have been intended as dwellings for the slaves, or, while the Emperor resided in the Palace, they might be lodgings for the Prætorian soldiers.

In the interior of the building are two or three specimens of arches, formed of segments of circles meeting in a point at the vertex, but they have the appearance of being more modern than the rest of the edifice. The style of the whole resembles that of the buildings of Palmyra and Balbec, which were probably erected about the same period, and several circumstances indicate a decline of architectonic taste; such are the columns standing on consoles projecting from the walls, which give them the appearance of hanging in the air; the swollen frizes; the pediments whose horizontal entablatures are broken in the form of arches; and the fantastic forms of the sculpture. In pl. xiv. is given a general plan of this Palace, and an elevation of its Southern front.

From such descriptions as those we have given, and the writings of Vitruvius, Palladio has endeavoured to trace the plan of a Roman dwelling-house; and though it is likely enough that a variety of modes of distribution prevailed among a people possessing such a taste for magnificence as the Romans exhibited in their public buildings, yet the general features may be considered correct. The arrangement which Palladio has adopted, is nearly as follows.

The entrance was by a vestibule on the South side, and a door led from this to the *atrium*, or what would be now called the grand hall; this was generally adorned with the busts, arms, and trophies of the ancestors of the family. To the right and left of the *atrium*, but without any communication with it, were the servants' offices. On the North side was the *tablinum*, an apartment in which the family records seem to have been kept, or it might be a sort of office where the master of the house transacted business relating to his estate. Between the *atrium* and the servants' offices were the passages which led to the *cavædium*, a kind of square court, which, according to Vitruvius, was of five different kinds; *viz.* the Tuscan, which was open at the top, and had a portion of the roof projecting from the walls, so as to throw the rain which fell on the top of the building into the middle of the court; the Corinthian, which was similar to the former, only the extremities of the roof of the house were supported by columns surrounding the open part of the court; the Tetrastyle, so called, from the number of its columns, which were placed one at each angle of the projecting roof; the *Displuviatum*, which was also open at the top, but in which the roof of the house did not project over any part of it, the rain-water being carried off by a gutter behind the tops of the four walls of the court; and lastly, the *Testudinatum*, in which the whole court was covered by a roof; this was done where the span was not great, and dwelling rooms were then made over the court.

The columns of the *cavædium* were sometimes made high enough to include the two stories of which the building was composed; in this respect, the *cavædium* differed from the interior peristyle of a hypæthral Temple; the latter containing two Orders of columns placed one above another

On the right and left of the *cavædium* was a *triclinium* with its *procœton*, or anteroom; beyond these, on one side of the house, were the baths; and on the other, the *cubiculi*, or bed-rooms. Through the Northern colonnade of the *cavædium* was the entrance into the *basilica*, a hall, in which, probably, the master of the house, as a magistrate, or lord of some territory, gave judgment to his clients.

On the right of this hall was the *pinacotheca*, a room containing paintings; on the left were the libraries, and between the *basilica* and the rooms just mentioned, were passages leading into a large *peristylium*, the right and left sides of which were occupied by servants' rooms; and on the Northern side were the different *œci*, or halls where the family seem to have resided, and where they generally dined; probably they were more particularly appropriated to the mistress of the house. The principal of these was the Egyptian *œcus*, which was placed in the centre, and appears to have had two Orders of columns, one above another, all round the interior, with a floor between the two Orders, equal in breadth to the distance from the lower columns to the walls: above this floor was a passage, open towards the exterior of the house, and windows were formed between the upper columns to give light to the interior. On one side of this apartment was the Corinthian *œcus*, which differed from the Egyptian, in having but one Order of columns, and these rested either on the ground, or on a *podium;* this hall was covered by a hemicylindrical ceiling. On the other side was the tetrastyle *œcus*, so called, perhaps, from four columns placed in the interior, one near each angle; and, on the North, was the Cyzicene *œcus*, a name given by the Greeks, apparently, to those rooms which admitted of two dining couches, or tables, placed opposite each other, and which had windows, or doors, opening to the garden.

The disposition above given is supposed to approach nearly to what Vitruvius intended for the houses of persons of the highest rank; he recommends that bed-chambers and libraries should be situated with a view towards the East, that they may have the benefit of the morning sun; that time of day being the most proper for study. The baths and winter *triclinia* should be situated towards the West, for the benefit of the setting sun, because the bathing and dining took place in the evening; and the summer *triclinia* are directed to be placed on the Eastern side of the house, for the sake of coolness; but it is not to be supposed that a strict adherence to these rules was always possible.

Vitruvius describes also the dispositions of houses for traders and agriculturists, but it will be needless to mention them.

The proportions of the apartments in Roman houses.

The propriety of adhering to a system of proportions, in the distribution of the parts of an edifice, seems to have been fully recognised in the time of Vitruvius; since this writer gives, as a reason for making the proportion of the length, breadth, and height of apartments to vary with their absolute length, that, if they were otherwise, the minor parts would either appear too diminutive, or too clumsy.

In the IVth and Vth Chapters of the VIth Book, he states, as follows, what those proportions should be in the principal divisions of a dwelling-house. In the *atria*, or entrance courts, the breadth should be to the length in a ratio which, when simplified, is either that of 1 to $\sqrt{2}$, of 1 to $1\frac{1}{2}$, or of 1 to $1\frac{2}{3}$; but he has omitted to give the absolute lengths to which these breadths are respectively applicable. The width of the uncovered part he makes equal to one-third, or one-fourth of the whole breadth; the height of the ceiling of the covered part, up to the lower side of the beams, is made equal to three-quarters of the length of the court; another fourth is occupied by the depth of the *lacunaria*, or panels, and by the thickness of the roof above them. Of the *alæ*, or passages on the sides of the *atrium*, the breadth varies from one-fifth to one-third of the length when the latter varies from 30 to 100 feet, in order, no doubt, that the apparent forms of the short and long passages may be nearly equalized. The breadth of the *tablinum* is made to depend on that of the *atrium ;* when the latter is from 20 to 60 feet, the former varies from two-thirds to two-fifths of such breadth; what relation the breadth of the *tablinum* should bear to its length, he does not say, and from this silence it may be presumed that the length was equal to the whole breadth of the *atrium;* the height of the *tablinum* to the under side of the beams is equal to 1⅛ of its breadth. Of the peristyles, the width is directed to be equal to three-fourths of the length. The lengths of the *triclinia* are to be equal to twice their breadths, and their heights are to be an arithmetical mean between the length and breadth. But for *exedræ* and *œci*, when square, Vitruvius would have their lengths, or breadths, equal to two-thirds of their heights.

The interior of Grecian buildings seems to have had but few decorations, and to connect the walls with the ceiling, the builder contented himself with an architrave, having mouldings, of small projection, similar to those on the exterior. But, in the Roman edifices, the whole entablature was introduced in the interior, when the building was spacious, and a display of richness required. The cornice, though generally objected to in the interior, because it does not there serve the purpose for which its projection was intended; *viz.* to protect the lower part of the entablature from the rain which fell on the roof; yet, perhaps, is not entirely misplaced, because it may seem to be required for the support of the ceiling.

The ornaments on the ceilings, both of the Roman and Grecian buildings, were generally panels sunk below the surface, as has been shown; and this seems to have been suggested by the crossing of the beams of the roof, which would necessarily leave such coffers between the beams.

Roofs of Roman houses.

The roofs of the ancient rectangular houses of Italy were, perhaps, originally made with two or four inclined planes terminating in a point, or in a ridge at top. The lower extremities of the roof either projected beyond the walls, to throw off the rain, or a parapet was formed at the top of the wall, and a gutter, at the foot of the sloping roof behind it, carried off the water through pipes.

The Ancients considered pediment roofs as objects of the greatest dignity in an edifice; and such were, till the time of Julius Cæsar, only employed to adorn the Temples of the Gods. That Emperor, who had obtained leave from the Senate to wear constantly a crown of laurel about his head, by permission from the same Body caused a pediment to be constructed over his Palace; and from that time they became general.

In some Countries the roof of the building is made horizontal that it may serve as a place of exercise for the inhabitants; but, in general, it is made with a certain inclination, in one or more planes, in order to throw off the rain or snow. The elevation of these planes has always been different in different parts of the World. In those regions wherein rain or snow is most abundant, we find, as is observed by Vitruvius, that the roofs are most elevated, in order to let it flow off most easily; Nature and observation having taught men the form of a roof which is best adapted to their circumstances. The roofs of buildings in Egypt and Syria were generally flat; those of the Grecian Temples, having their heights equal to about one-ninth of their horizontal breadths, make angles of about 12½ degrees with the horizon. In Italy, which is situated more to the North than Greece, the heights of the roofs are about one-fifth of their horizontal breadths, which makes the inclination to the horizon equal to about 23½ degrees. And, subsequently to the Roman times, the roofs of buildings in the North of Europe have been made to form an angle of as much as 60 degrees with the horizon, or the pediments have been made in the form of equilateral triangles; the abundance of snow seeming to require such a slope to secure the edifice from damage.

Stairs.

Vitruvius, in speaking of the steps about a Temple, prescribes that they should be 10 inches high and 18 inches broad, but of those within a building, he makes the proportion between the height and breadth as 3 to 4; both of these rules, but the latter particularly, would now be considered as making the steps much too steep. The Ancients chose to make the ascent from one level to another by an odd number of steps, because, in mounting, they considered it fortunate to begin and end the ascent with the same foot.

Chimney

We have before observed that no chimneys have been discovered in the ruins of Pompeii or Herculaneum, and hence some have inferred that those conveniences were unknown or unused by the Romans; it may, however, be observed, that Palladio mentions the discovery of two ancient chimney-pieces, one at Baia, and the other at Civita Vecchia. He says they stood in the middle of the room, and consisted of columns supporting architraves, on which were placed the pyramids, or funnels, through which the smoke was conveyed. Such chimneys have been noticed by late travellers in some of the inns of the country. See further on this point in our *Miscellaneous Division*, CHIMNEY.

Doors a
window

In the walls of buildings are, necessarily, left apertures to serve as doors and windows; and though little is delivered by Vitruvius concerning those of dwelling-houses, it is probable enough that their proportions and ornaments did not differ materially from those of the doors of Temples, which we have before described. The general proportions between the heights and breadths of these apertures are recommended by Vitruvius to be as 3 to 2, or as 2 to 1; for which no better reason is assigned than that musical strings, which have those ratios to each other, *viz.* the fifths and octaves, produce sounds which harmonize with each other; and he seems to suppose that a proportion which was agreeable to the ear, must also be so to the eye.

Of the manner in which the windows opened, we only know that, in such apartments as the Cyzicene *œcus*, (Vitr. book vi. ch. v.) they opened like doors for the convenience of entering the garden. Some of the windows in the houses of Pompeii were glazed.

CHAPTER IV.

Works of Public Utility and Ornament.

These denominations may be considered as comprehending the *Fora*, the *Portici*, the Triumphal Monuments, the Bridges, Aqueducts, and even the Tombs of the Romans. Some examples of each of these species of buildings are still in existence; and the principal of them we purpose now to describe.

An important feature in a Roman city was the *Forum*, which, within its area, contained the buildings intended for the meetings of the Magistrates, the Courts of justice, the prisons, and the offices for the management of the public revenue. It served, also, as the public market-place, and, occasionally, as a theatre for exhibiting the combats of the gladiators.

e Fora Italy.

The *Fora* were sometimes of a simple, and often of a complex character. We have spoken largely of those in Rome in our *Miscellaneous Division*, (Forum,) and shall here, therefore, be brief. The great and ancient *Forum* at Rome was situated between the Capitoline and Palatine Hills, but its outline is now difficult to be traced; within its limits are the Arch of Septimius Severus, the Temple of Concord, and the Curia or Senate-House, besides the columns supposed to form part of the Temple of Jupiter Stator.

In the same city were several *Fora* bearing the names of different Emperors; of these, the *Forum* of Nerva is supposed to have been 367 feet long, and 164 feet wide, and nearly of a rectangular form. At one extremity were five arched entrances, and at the opposite extremity was the fine Temple of Nerva before described. The interiors of the two side walls of the *Forum* were ornamented with Corinthian pilasters, having columns of the same Order detached in front of them.

If we may trust to the representations given by Piranesi, the *Forum* of Trajan, which stood at the foot of the Quirinal Hill, must have been a magnificent work. The whole length is supposed to be 1150 feet, its general breadth 470 feet, and along the sides were rows of houses and columns. At one extremity stood the Temple of Trajan, and, on the opposite side, the Triumphal Arch; about the centre stood the splendid *Basilica Ulpiana*, and near it the grand Triumphal Column of the Emperor.

A *Forum* discovered at Herculaneum is of a rectangular form, 220 feet long, and 140 feet wide; the interior face of the enclosing wall was ornamented with half-columns attached to it; at one extremity was a rectangular and two semicircular recesses, and at a distance from the walls was an interior peristyle. One extremity of the *Forum* opened into a street, on the opposite side of which are the remains of two Temples. That at Pompeii is in good preservation, and contains several interesting ruins.

The *Forum* at Fano, in the March of Ancona, had, at one extremity, a *Basilica* built by Vitruvius himself; according to his description, the portico of the Temple of Augustus joined that side of the *Basilica* which was furthest from the centre of the *Forum*; and at the opposite end of the latter was a Temple of Jupiter. The Treasury, the Prison, and the *Curia* are stated, by him, to be situated upon the longer sides of the *Forum*, on the exterior of the shops which surrounded the area.

In the 1st Chapter of the Vth Book, Vitruvius gives a few general rules for the design of a *Forum*, which we may suppose to be such as he would have adopted where local or other circumstances did not happen to oppose themselves to the execution of a regular arrangement. He directs that it should contain a large rectangular area, the breadth of which may be about two-thirds of its length, and that the interior should be surrounded by two Orders of columns, one above another, at a small distance from the walls; the lengths of the upper columns are recommended to be about three-quarters of the length of the lower ones; behind the lower columns are to be arranged the shops of the bankers and other traders, and, on the upper floor, the apartments for persons employed in collecting and administering the public revenue.

The Basilica.

At one extremity of the *Forum* was to be placed a *Basilica*, serving as a Court of Justice and as an Exchange for the merchants; this is described as a rectangular building, the breadth of which is supposed to be from one-third to one-half of its length. Within the four walls of the *Basilica*, and at some distance from them, was a row of columns on each of the four sides, leaving two tiers of passages one above another between them and the walls; the upper passage seems to have been covered with a roof of the kind called testudinated; that is, having a flat top with curved sides rising from the entablatures of the columns. Behind, and attached to each column, was what Vitruvius calls a *parastata*, which seems to have been a pilaster, or an upright post to support the beams which bore the floor of the upper tier of passages, which was at a height above the pavement equal to one-half or two-thirds of the height of the columns. Under one of these passages, and at the extremity of a line drawn through the centre of the *Forum*, parallel to one of its sides, was to be the Tribunal of the Judge.

Triumphal Arch of Titus,

The Romans, in order to perpetuate their great achievements, their public acts of beneficence, and sometimes, perhaps, merely to gratify their vanity, erected Triumphal Arches, of which several still remain to attest the bad taste prevalent at the time of their construction. The Arch of Titus is that which possesses the first claim to our attention, having been erected before the period of any considerable decline of architectonic genius; though even this is, perhaps, justly characterised as being too rich to be elegant.

Its plan is rectangular, and it is perforated by a single passage, covered by a hemicylindrical vault. The length is 49 feet, breadth 16½ feet, and the whole height of the building is equal to its length. The width of the aperture is 19 feet, and on each side of it, on both fronts, are two fluted marble columns of the Composite Order, standing on pedestals 9 feet high, and supporting an entablature; this member is adorned with sculpture in bas relief representing the Triumph of Titus after the conquest of Judea. Above the entablature is an Attic Order, 12 feet high, on which is expressed the apotheosis of the Emperor. The Arch is semicircular, and springs from a horizontal moulding, called the *impost*, which crosses the front of the building at about 22 feet from the ground.

The height of the columns is 22.065 feet, and the lower diameter is 2.07 feet, consequently the height of the column is equal to 10.6 diameters. The base is similar to that of the columns belonging to the Temple of Jupiter Stator, and the height of the volutes in the capital is equal to half a diameter. The architrave is divided into three faciæ, the lower of which is vertically over the circumference of the top of the shaft; the frize is highly sculptured, and there are both dentels and modillons in the cornice; the height of the entablature is 5.245 feet, or $\frac{1}{43}$ of that of the column. See fig. 6, pl. xi.

of Severus.

The Triumphal Arch of Severus is, like the others, of a rectangular form; its length is 75.5 feet, width 19.75 feet, and its whole height 68 feet. In its length are three arches, of which that in the centre is 23 feet broad, and each of the others 11.48 feet. These arches spring from imposts on the piers; the crowns of the side arches rise only to the level of the imposts of that in the centre, and all of them communicate by a transverse passage, covered also by a hemicylindrical vault. Each façade is ornamented with four fluted Composite columns standing on pedestals 13 feet high; behind each column is a fluted pilaster, and above is an entablature which is broken over each column; over this is an Attic wall 19 feet high, with one large panel in front, containing an inscription, and having a small pedestal or Attic pilaster at each extremity; the whole is crowned by a small entablature. The *dado* or cubical part of each pedestal under the columns is ornamented with figures, and the whole face of the building above the side arches is covered with sculpture, representing Victories, Rivers, and Seasons. The soffits of the arches are panelled in square forms, and there are modillons in the impost mouldings, which are extended through the whole depth of the building.

The height of the columns is 27.847 feet, and the lower diameter is 2.837 feet. The base and capital very much resemble those of the Arch of Titus, but the shaft is different, being of a cylindrical form up to one-third of its height above the base, from which place it diminishes gradually to the top, whereas the other diminishes from the base to the capital. The architrave is divided into two faciæ; the frize is plain and very low, and there are no modillons in the cornice. The height of the whole entablature is 6.689 feet, or $\frac{1}{4.1}$ of the height of the column; this member is far more meagre than the entablature of the arch last mentioned, and its vertical breaks produce a confused appearance.

of the Goldsmiths,

The Arch of the Goldsmiths, at Rome, which is said to have been erected also in honour of Severus, has but one passage through it, and this, which is 9 feet wide, is remarkable for being covered by a horizontal ceiling. At the extremities of the piers, on each side, are two panelled pilasters standing on a podium, with Composite capitals, and in the entablature is a swelled frize. The whole face of the work is covered with sculpture.

of Janus,

The Arch of Janus, at Rome, is a square building about 70 feet in length and width, and the same in height, and is perforated by two hemicylindrical vaults at right angles with each other. On each of the four faces is a semicircular arch, of which the archivolts spring from imposts. The lower part of the building forms a podium with a cornice; and, between this and the impost of the arch on each face are six niches, *viz.* three on each pier, with heads in the form of quadrants of spheres; these have no imposts, and the archivolt is continued to the foot of the niche. Above the imposts of the arch, on each face of the building, are three other niches similar to those below, and over the niches is a horizontal entablature, which is crowned by a high Attic. There are no columns on any of the faces.

of Constantine,

The Arch of Constantine, at Rome, was raised by the Senate with materials taken from the arches of some of the former Emperors; among which the parts belonging to that of Trajan are very distinguishable by their superior quality. Of all the Triumphal Arches this is the richest and in the best preservation, but it exhibits, at the same time, a melancholy proof of the declining state of the Art at that period. Like the Arch of Severus, it consists of three passages covered by hemicylindrical vaults, the crowns of the two side-arches rising only to the level of the impost of that in the centre. Its length in front is 81 feet, its height 70 feet, and its depth 21.75 feet. The span of the centre arch is 21.4 feet, and the height of its vertex from the ground, 38.2 feet. The imposts of the arches return on the faces of the piers, and are ornamented with dentels and modillons. The building is formed of white statuary marble, and each front is adorned with four columns of jaune antique marble, of the Corinthian Order. These stand on pedestals which are panelled, and have a figure sculptured in front of each, and the bases of the pedestals are continued round the piers. The plinths in the bases of the columns are connected with the cornices of the pedestals by an inverted cavetto. The shafts of the columns, as well as those in the Arch of Severus, are cylindrical up to one-third of their height, and, from thence, they begin to diminish in a curvilinear form; they are fluted with twenty-four channels, which are cabled, or filled up to one-third o their height by a reed. A fluted pilaster is placed behind each column. The entablature is broken over each column, and above it is a high Attic filled with sculpture; over that part of the entablature which is vertically above the columns, are pedestals supporting Dacian captives. The faces of the building in the intervals of the columns, and the soffits and sides of the arches are ornamented with panels, in which figures are sculptured; and there is an ascent to the top by a staircase in the interior. An elevation and plan of this building is given in pl. xiv.

The height of the columns is 28.037 feet, and the lower diameter is 2.902 feet. The base is Attic, but the upper torus is double. The architrave is divided into three faciæ, all of which incline inward at their upper extremities; the frize is plain; there are both dentels and modillons in the cornice, but the latter are thinly distributed over a large and plain facia; the corona is small, and all the parts of the cornice have great projections. The height of the whole entablature is 6.94 feet, or nearly one-fourth of the height of the column.

Out of Rome are many Arches, chiefly remarkable for the indications they afford of a corrupt taste; and it may be, therefore, sufficient merely to describe their features in a general way. The triumphal edifice of Gallienus, at Verona, forms a double gateway, consisting of two arches, with an entablature and pediments, supported by Corinthian columns, placed one on each side of each gate. Above these is a second story containing a row of semicircular arches, with architraves continued to the foot; two of these arches, which stand over the pier between those below, have fluted Corinthian pilasters on each side, supporting a pediment. This story is crowned by a general horizontal entablature, which is broken over the space occupied by the two pediments, and is supported by two twisted Corinthian columns. The third story contains a row of semicircular arches, above those in the second story, but larger. Over these is the upper entablature of the building, which is broken above every alternate arch, and supported by a pilaster at each extremity. Below the ground-floor are elliptical vaults. The breadth of the building is 52 feet, the height from the ground to the soffits of the principal arches is 23 feet, and the whole height is 66 feet. Some of the members of this arch seem to have been the originals of those peculiarities which distinguished the works of the Italian artists in the XVth and XVIth centuries.

of Galli at Ver

The Arch of Trajan, on the pier at Ancona, is also of a rectangular form, and consists of one semicircular arch with a console in the vertex. In its façade are

of Tr at An

four Corinthian half-columns with fluted shafts, and Attic bases, and pedestals beneath. The entablature is continuous over the two middle columns, and broken over the two extreme ones. Above this is a high Attic with small pilasters over the extreme columns, and one general dado over the archway. The profile of the entablature is very coarse; the soffit of the arch is unornamented, and there is a rectangular tablet between the columns on each side of the arch.

ugustus, Rimini.

The Arch of Augustus, at Rimini, appears to have been, when entire, 124 feet long and 88 feet high, to the top of the entablature. It consists of one semicircular arch springing from imposts, and, on each side, a Corinthian half-column, standing on a pedestal which projects from the basement; at each extremity of the façade is a Corinthian pilaster; above these is the entablature, and over the archway a pediment. The entablature is broken over each column, and the pediment, if it formed part of the original design, is a remarkable proof of a declining taste in Art, even in the Augustan Age; since, instead of rising from the extremities of the horizontal cornice, it rises from two points vertically over the interior sides of the columns, so that its span is only equal to the intercolumniation. The sides of the modillons in the oblique entablatures of the pediment are neither vertical nor perpendicular to those entablatures, but are formed between both those directions.

At Orange is a Triumphal Arch of Roman workmanship, remarkable for being of a square form, and for the crown of the side arches rising above the horizontal courses of that in the centre; all the archivolts spring from pilasters, and the soffits are richly panelled. A Corinthian fluted column stands at every angle and on each side of the centre arch. The entablature is continuous over the two middle columns, and above this is a pediment with a double Attic. The whole façade is covered with sculpture. The sides of the building are like the front, but without arches, and are ornamented with figures in alto relievo. The bases of the columns resemble two Attic bases placed one over the other, and the lower one rests on a pedestal.

At Bara, in Spain, is a Triumphal Arch of a semicircular form, with a simple archivolt springing from imposts; on each side are two fluted pilasters, with capitals resembling the Corinthian, on a rusticated podium. The architrave and frize are plain, and there are modillons in the cornice. The whole building may be considered as a specimen of the Roman Architecture in its best state. Near this place are excavations, in the sides of rocks, which have served as sepulchres, probably, in very ancient times.

drian, thens.

Returning towards the East, we come, next, to Athens, where still exists that which is called the Arch of Hadrian; this, when in its perfect state, consisted of a semicircular-headed aperture formed in a wall; the archivolt rises from pilasters which terminate in a capital resembling the Corinthian. On each side of the arch there are two fluted Corinthian columns supporting a horizontal entablature, above which is another tier consisting of four Corinthian columns, supporting, also, an entablature with a pediment over the middle interval. It has been thought that this work, consisting merely of a wall, ornamented as above described, could hardly have been intended for a Triumphal Arch, and that it may rather have formed the entrance to a portico.

Arch at Palmyra.

It would be improper to omit mentioning here, a Triumphal Arch which exists among the ruins of Palmyra. It consists of three semicircular-headed apertures, and the crowns of the side-arches do not rise so high as the imposts of that in the centre. The whole façade is divided vertically into three parts, of which the centre projects before the wings; all the salient and rentrant angles are adorned with pilasters of a Composite Order, having their faces panelled and filled with sculptured foliage. The pilasters support an entablature which is broken to follow the planes of the façade. The frize is enriched with sculpture, and the central part of the entablature is crowned by a pediment. Over one of the lesser arches is a niche which is crowned in like manner.

The Columns of Trajan and Antonine.

Besides Triumphal Arches, the Romans raised lofty Columns to commemorate the remarkable circumstances which tended to exalt the grandeur of their Nation; two of the most superb of these monuments are still to be seen at Rome, *viz.* the Columns of Trajan and of Antonine, on which, as on Historical Tablets, are sculptured the events of the lives of those Princes. And amidst the ruins of Temples, Theatres, and other splendid edifices of the Eternal City, these seem to have been respected by Time, and by Barbarians both ancient and modern. The Column of Trajan is of Parian marble, 125 feet high including the pedestal; the length of the shaft is 90 feet; its lower diameter 12 feet, and its upper 10⅔ feet, so that the difference of the diameters is about one-ninth of the lower. The ascent to the abacus was by steps within, and, on it, was formerly a colossal statue of the Emperor. The Column of Antonine stands on a double pedestal, placed one above the other, of which the lower one has been but lately discovered, and that, by making an excavation at the foot of the column.

The spiral direction of the sculpture on these Historic columns has been ingeniously adopted to give the story a continuity, which horizontal rings would have interrupted. Mr. Forsyth observes, that the columns are of no Order of Architecture; that of Trajan has a Tuscan base and capital, and a Doric shaft and pedestal, with Corinthian mouldings.

The Pillars of Phocas and Pompey.

The Column of Phocas, at Rome, is a Corinthian Pillar, which was erected in the VIIth century in honour of that Emperor. That which is called Pompey's Pillar, near Alexandria, is, probably, a monument of a similar kind, and, therefore, may be mentioned in this place. It is executed in granite, of a mixed Corinthian Order, its diameter is 8 feet, and height 80 feet, exclusive of the pedestal, whose height is 10 feet. Dr. Clarke is of opinion that it was erected by Cæsar in honour of Pompey; on the other hand, Dr. White supposes it was, originally, within the precincts, and an accompaniment to the Temple of Serapis, and, consequently, that it was a work of one of the Ptolemies. Some think it was elevated in honour of Hadrian, or Severus, or Dioclesian, for the inscription on the pedestal is so much obliterated that it is impossible to ascertain which of these Emperors is meant. The shaft is said to be more ancient than either the capital or the pedestal; the latter is supported on a block of stone, which appears to have been part of a more ancient ruin, and this block is surrounded by sepulchral fragments of ancient Egyptian monuments.

Roman Bridges.

No Works of the Romans are more deserving of notice than their Bridges, on account of the great utility of those edifices in facilitating the communication between the different Cities and Provinces of the Empire. If the Romans thought the conquest of any Country was not complete till a military road was made through it, much more must they have thought it of importance to the security of their possessions that the rivers which flowed between them should be subdued by permanent buildings which might, at all times, permit a free passage over them. Some of the Bridges of Rome existed in the time of the Republic, but on account of the changes they subsequently underwent, it is impossible to say in what manner they were at first formed; it is certain that some were of timber, but there seems no reason to doubt that, in others, the roadway was supported by voussoirs of stone, arranged in a circular order.

As the principal Bridges executed by the Romans have been described, *ad v.*, in our *Miscellaneous Division*, it will be unnecessary to mention them here; and we, therefore, proceed to an account of the Aqueducts which supplied the city with water.

Aqueducts.

An Aqueduct in the time of the Romans was a work of no less consequence than a bridge, and the construction of each was in some respects similar. The former conveyed the water from the rivers, or from an original reservoir, to the place required; and being necessarily horizontal, or having but small declivity, whenever hills or rocks intervened, it was necessary to cut through them, and when the course of the water lay across a valley, the canal was supported on arches of masonry, which were, sometimes, of vast height, and placed in two, and even three, tiers, one over another. No reason, except it be that of making a display of wealth and magnificence, can be given for incurring the expense of these extensive canals, since an equal supply might have been obtained in a more economical manner by forming subterranean tunnels, or a system of pipes from the reservoir to the place of delivery; these might have followed all the inequalities of the ground, and it would have been only necessary to take care that, in no part of the course, the tunnel, or pipes, were on a higher level than that of the reservoir. It has been supposed that the Ancients were ignorant that water, flowing in the branches of a bent tube, will rise to the same vertical height as that in the reservoir from whence it proceeds; but this opinion is by no means to be admitted as a reason for their executing these works, since the hydrostatical fact just mentioned is distinctly affirmed by Pliny, and it appears from Vitruvius, (book viii. ch. vii.) that the Romans actually used pipes of lead for the conveyance of water to their houses and baths.

The most ancient Aqueducts which brought water to Rome are those called the Martian, the Appian, and the Claudian. The first, which brings its supply from the Teverone, was erected by Quintus Martius, 312 years before Christ; it consists of two canals, one above the other, supported by an upper and under row of semicircular-headed arches, the apertures of which are each equal to 16 feet; and the height of the whole work is about 70 feet. The second was erected during the same year by the Censor Appius Claudius, and is remarkable for the form of its transverse section, which is narrower at top than at bottom. The last was built by the Emperor Claudius of squared stone, and its whole extent is 46 miles. The canal is borne on a long line of semicircular arches 20 feet wide, supported on lofty piers; and the height of the crowns of the arches above the valley, is, in some places, about 72 feet. Elevations of three of the most celebrated Aqueducts are given in plate xiii. At Vicovaro, near Tivoli, there is a canal more than a mile long, 4 feet broad, and 5 feet deep, which forms part of an aqueduct, and is cut through the solid rock.

It has been remarked, that though, in some cases, water might have been brought in a straight line to the city, yet the Aqueduct has been constructed with several bendings, by which the whole length of the work is considerably increased; some have supposed that this was to avoid the expense of raising the arches to an excessive height over the low grounds, and others, that it was to diminish the velocity of the water, which, if great, might damage the bed, or come less pure to the city. According to Montfaucon, there were formed at intervals along the line of canal, reservoirs called *castella*, in which the water, by expanding, might purify itself; these were a sort of round towers of masonry, raised, of course, to the same height as the canal, and sometimes highly ornamented. The same author observes, also, that, in various places, pits were sunk below the general bed of the canal, in which the water, remaining at rest, might deposit the earthy particles which it conveyed. According to Vitruvius, an Aqueduct should be arched over to prevent, as much as possible, the Sun from shining on the water. Vitruvius also states, in the VIIth Chapter of the VIIIth Book, that, when pipes, for the conveyance of water, pass across the bottom of a valley, it is necessary to form what he calls a *venter;* that is, a subterranean reservoir, in which the water may diffuse itself; and thus, he observes, the force will be diminished, with which the water, by its swelling, meaning its hydrostatical pressure, would act against the pipes, to burst their joints. In such valleys, also, and even in horizontal plains, he proposes that vertical pipes, open at top, should be raised, in order that the air which is conveyed with the water may, thereby, escape. In modern practice such air-pipes, or valves equivalent to them, are placed, not at the bottoms of valleys, but wherever the pipes form a bend the convexity of which is upwards, in order to permit the escape of the air which, in such places, would rest and impede, or entirely stop the movement of the water.

Of Roman Tomb

We may conclude this Chapter with a short notice of the Tombs erected by the Romans to contain the bodies of their dead: some of these were intended for the interment of individuals or families, and some were for the public in general. The latter were merely vaults excavated in the ground, but of such extent that they have been compared to subterranean cities, the others were cylindrical, conical, or pyramidal towers, containing within them ranges of vaults, connected with each other, in which the bodies were deposited.

Of the Horat

On the Appian Way is a great and ancient Tomb, probably constructed by Etruscan artificers; it consists of a squre basement 45 feet each way, on which are raised five masses of earth, in the form of frusta of cones, reveted with masonry. Four of these cones are 10 feet in diameter at bottom, and are placed, one at each angle of the basement; the fifth is larger, and is placed between the others, and the foot of each cone is connected with the top of the basement by an inverted cavetto. The Tomb is supposed to have been raised over the bodies of the Horatii; but this opinion is extremely uncertain, and, indeed, is founded only upon the apparent antiquity of the workmanship. Near it is what has been taken for another Tomb, but is more generally supposed to have been a little Temple dedicated to the God Redicolus, after the retreat of Hannibal from Rome. Mr. Forsyth thinks, from the rich chiseling it exhibits, that it was erected as late as the time of Severus, and that it was destroyed soon after it was built.

The principal Tombs at Rome are those of Caius Cestus, of the Emperor Hadrian, and of Cecilia Metella. The first is a simple pyramid raised on a square plan, each side of which is 102 feet, and its height is nearly the same. In the centre of the pyramid is a rectangular cell, 20 feet long and 13 feet broad; and at one of its extremities is a small niche, which, probably, contained the sarcophagus. At each angle of the pyramid is a Doric column, seemingly intended as an ornament, for it does not support any thing.

The Tomb of Hadrian, now the Castle of St. Angelo, consisted of a square basement, the length of the sides of which is 170 feet. Above this was placed a cylindrical tower, 115 feet diameter, formed by a thin wall of tufo, and, probably, at one time, surrounded by a colonnade. The interior is crossed by the modern stairs leading to the apartments on the upper floor, which were built by Pope Paul III.

The Mausoleum of Cecilia Metella, which was built by Crassus, is a plain, circular building, 90 feet in diameter and 62 feet high, standing on a basement of the same form. The body of the tomb is of travertine stone, and, at the top, is a circular frize of marble, adorned with sculpture, representing rams' heads and garlands. In the interior is a circular cell, 19 feet in diameter, to which there is an entrance by a passage on the exterior.

Near Capua is an ancient Tomb, consisting of a cubical basement 21 feet long, and of the same height, with a door in one of the sides crowned by a semicircular arch. Above this is a lofty building, with a plain, round turret on each angle. The wall between every two turrets is cylindrical with its concavity outwards, and in its centre is a small projection, containing a rectangular window, which is crowned by a pediment, and there is a semicircular niche on each side. Above the centre of the Tomb is a small round tower, ornamented with Doric columns supporting an entablature, and the whole is covered by a low cupola. Between the columns are semicircular-headed recesses ornamented with pateræ. On what occasion this building was erected it is now impossible to form an opinion, but the workmanship is Roman.

In the *Antiquities of Magna Græcia* is given a representation of a remarkable monument, at Agrigentum, in Sicily, which is commonly considered as the Tomb of Theron. It is a pile of building about 25 feet high, in the form of a frustum of a pyramid, standing on a quadrangular basement 13 feet in length, and as much in breadth. The building is divided into two stories nearly equal in height, of which the lower is a plain stylobata, crowned by a projecting cornice. The second has a blank window, surrounded by mouldings, in each front; the angles of this story are terminated by fluted columns with Ionic capitals and bases, and the whole is surmounted by an entablature, of which the cornice is wanting. There is no regular doorway; and, no doubt, when the sarcophagus was placed in the Tomb, the aperture was built up. The columns, which, instead of being in vertical positions, incline with the walls, have Attic bases, and their capitals resemble those employed in Roman buildings. Lastly, there are triglyphs in the frize, which, also, converge towards the vertex of the pyramid.

Tomb at Valence,

At Valence, on the Rhone, is an ancient Tomb, said to have belonged to the Martian family; its plan is a perfect square and its height is equal to twice the length of each face. At each angle is a column let into the masonry and standing on a pedestal, and, on each face, is a semicircular arch springing from columns Above the latter is an entablature, and the whole is crowned by a pyramid, the height of which is about half of that of the whole Tomb. At Vienne is, also, a singular work, probably intended for a Tomb, and supposed to be Roman. It is similar to the last, but open on all sides, with a column at each angle, standing on a pedestal. In each face is a semicircular arch springing from square piers; above is a horizontal entablature, which is crowned by a lofty obelisk. The capitals of the columns and the archivolts are unwrought.

at Vienne,

at St. Remi.

At St. Remi, in Provence, is a Mausoleum which, also, bears marks of Roman workmanship; at bottom is a pedestal on two steps, with a sculptured dado, and, on this, is a square story with semicircular arches springing from pilasters. At each angle is a fluted column of an Order resembling the Corinthian, and these support an entablature with sculptured frize. Above is a circular tower with Corinthian columns on a general circular base, and, over these, is an entablature crowned by a conical dome.

Tombs at Pompeii.

The excavations at Pompeii, which have brought to light so many specimens of ancient Architecture, have, also, made us acquainted with several Roman Tombs, which are so much the more interesting, as, having been buried in the earth during so many Ages, they cannot have suffered any change of form, from the caprices of men, since the period of their construction. They are, in general, small, and are placed near together, so as to form a sort of street of Tombs. See Gell's *Antiquities of Pompeii.*

Tomb at Mylassa.

In the IId volume of the *Ionian Antiquities* is given a representation of a sepulchral monument, about a quarter of a mile from Mylassa, in Asia Minor. This work, which was, probably, executed while the Romans were in possession of the Country, is raised upon a square plan; the lower part is a general pedestal, consisting of a plain dado with a base and cornice, and, in the pedestal, is a doorway to the chamber wherein the body was deposited. Above the pedestal, at each angle, is a square pillar, and between them are two elliptical columns on each face; the pillars support a simple entablature, above which are four courses of stones, forming a frustum of a pyramid, the sides of which are in the shape of steps; the lower part of the shafts of all the pillars is plain as far as one-third of their height; the whole above is fluted, and, between the pillars, the spaces are now quite open on each face, but, originally, they seem to have been filled with marble panels. The soffit of the roof is richly ornamented, and hollowed in the form of a triple square, the sides of each interior one being inscribed obliquely within the next exterior one.

Sepulchres of the Kings.

What are called the Sepulchres of the Kings, near Jerusalem, are, by M. Chateaubriand, supposed to be the Tombs of Herod the Tetrarch, and they are described by that traveller in the following manner. In the midst of a field is an excavation similar to the abandoned work of a quarry; a long and gentle descent leads to the bottom of the excavation, where an arcade has been formed, through which is the entrance to an open room cut in the rock; this room is 30 feet long, 30 feet wide, and 12 feet high. In the middle of the South side of the apartment is a recess, cut several feet deep in the rock; its section is square, and about the aperture are ornaments resembling those of the Doric Order; over the lintel is a sort of frize, containing triglyphs and metopes; in the centres of the latter are sculptured simple rings, and these are continued down the jambs. In the left-hand angle of the chamber is an open gallery, leading to another square chamber, in the sides of which are holes cut to contain the coffins. Three vaulted doorways lead from this to seven other chambers, of unequal sizes, which are, also, cut in the rock. Some of the sepulchral monuments near this place resemble in form those in the South of France, which have been just described.

We have had occasion to mention the employment of small bells, either as ornaments, or to keep away birds from the ancient Temples of Greece and Syria; and, it is from a monumental edifice we learn that bells, for similar purposes, were used in Italy at a very early period. Tintinnabula are said, by Pliny, to have been suspended by chains about a building of this kind which, he says, was erected by Porsenna, near Clusium; this must have been about 500 years before Christ. See LABYRINTH in our *Miscellaneous Division.*

CHAPTER V.

Works of Public Convenience and Pleasure.

We class under those heads the Theatres, Amphitheatres, Circi, and Baths of the Romans, all of which were objects of the utmost importance to that people, though there is found a considerable difference in their execution, some having their details rudely formed, while in others the utmost delicacy of ornament has been profusely lavished.

The Roman Theatres resembled those of the Greeks in being of a semicircular form; but, being situated within the cities, where the natural ground did not afford the means of supporting the seats, as was the case in most of the Grecian Theatres, it was necessary to carry them upon the upper surfaces of vaults, and to terminate them, on the exterior, by a lofty wall surrounding the edifice.

Pompey's Theatre, at Rome, seems to have been the most ancient stone building of the kind, and, even of this, the seats were probably made of wood, as it was several times consumed by fire. The second stone Theatre was erected by Julius Cæsar; and Augustus, afterwards, caused one to be constructed in honour of Marcellus, his sister's son; the ruins of this last still exist. Many others were, subsequently, erected in Rome and the Provinces.

The Theatre of Marcellus

The Theatre of Marcellus consists of a semicircular part, which contained the orchestra and the seats of the spectators, and of a rectangular part, in which were the *scena*, the *proscenium*, and the porticos. The *orchestra* occupied the most central part of the Theatre, and its diameter was equal to 172 feet; round its circumference were two concentric rows of hemicylindrical vaults supporting the *podium*, or wall in front of the level space at the foot of the seats, and, probably, serving to contain the animals destined for the exhibition of combats, which seem to have taken place in Theatres before Amphitheatres were constructed. Between the vaults of the first row, at intervals, are passages by which, probably, the animals were brought into the *arena*, or *orchestra*, and, at intervals, in the second row, are steps which led to the *podium*. On the exterior of the second row is a corridor, extending along the circumference, and receiving light from apertures above. Beyond this corridor were vaults, in directions diverging from the centre of the Theatre; some of these served as passages, and others contained the steps by which the common people ascended to the upper rows of seats, and those of the Equestrian Order to their places; on the exterior is the grand corridor formed by the double arcade surrounding the building. Between the extremities of the semicircular part and the flanks of the *proscenium* are passages, which probably served as entrances for the Nobles. Behind the centre of the *scena* was a vestibule, in which were steps leading to the parts under the *proscenium*, and on each side of the vestibule were the apartments for the performers and persons who had the care of the Theatre: on each flank of the *proscenium* was a covered portico for the convenience of the spectators in bad weather. The whole diameter of the Theatre is equal to 517 feet.

The semicircular front of the Theatre was adorned with two Orders of attached columns placed vertically above one another. The lower columns are of the Doric Order, and rest upon a platform which serves as a general base to the whole edifice, and is surrounded by three steps. These columns are without bases, and the fronts of their shafts project from the face of the wall about three-quarters of a diameter; and between every two columns is a semicircular-headed archway, formed by simple voussoirs springing from imposts in the wall, at points taken about two-thirds of the height of the column from the pavement. The columns next above were of the Ionic Order, and stood on plain pedestals resting on the entablature of the lower Order; and between every two columns is a semicircular arch similar to those below. Some have supposed that there was a row of Corinthian columns above the entablature of the second Order, but of this there is no proof.

According to the dimensions given by Degodetz, when reduced to English measures, it appears that the height of the Doric columns is 24.119 feet, and the lower diameter 3.198 feet. The exterior face of the architrave is vertically over the top of the shaft; the frize is ornamented with triglyphs, and the cornice contains a row of dentels partly concealed under the inclined soffit of the corona, the face of which, also, conceals the guttæ over the triglyphs. The height of the whole entablature is equal to 6.063 feet, or nearly one-quarter of the height of the column. The span of the arches between the piers is 8.794 feet; the breadth of the latter is 6.864 feet, their thickness is about 7 feet, and their height from the pavement to the level of the foot of each arch is 17.633 feet. An elevation of one of the columns in this tier is given at fig. 1. pl. x.

The height of the Ionic columns, in the upper Order, is 23.94 feet, and their lower diameter is 2.66 feet; therefore the height is equal to nine diameters. The architrave is divided into three faciæ, the upper extremities of which incline forward; the top of the cornice is destroyed, but there remains a row of dentels over which the corona must have been placed. The bases are of the Attic kind, and the columns stand on pedestals four feet high, the tops of which are on a level with the bottom of the aperture of the arch. The volutes of the capitals are very simple, and their planes are parallel to the exterior faces of the abaci. The fronts of the shafts of these columns, also, project about three-quarters of a diameter from the face of the wall.

The ruins of other Theatres of similar forms have been noticed at Herculaneum and Otricoli, in Italy; at Taormina and Ægesta, in Sicily, besides several in Asia Minor and Syria, which were erected during the plenitude of the Roman power in those parts of the World.

struc- of the man atres.

From the descriptions of Vitruvius, and from such remains of these edifices as still exist, it appears that the principles which regulated the construction of the Roman Theatres were nearly as follows. A circle was described with any convenient radius, which was probably about one-third of the radius of the whole building; the part included between the semicircumference and the diameter was occupied by seats for persons of Senatorial rank, and a wall, extending along the circumference of the semicircle, separated this space from the seats of the other spectators; a wall coinciding with the diameter, and produced each way till it was equal to twice the diameter, formed the front of the *proscenium* or *pulpitum*. The space occupied by the Senators corresponded with the *orchestra* in the Greek Theatres, only the floor of the latter was horizontal, whereas in the Roman Theatres it was an inclined plane rising towards the circumference.

An equilateral triangle being inscribed in the circle, and having one of its sides parallel to the above diameter, the wall of the *scena* was made coincident with that side; and this determined the breadth of the *pulpitum* on which the actors performed their parts. This *pulpitum* was made not more than five feet higher than the level of the *orchestra*, in order that the spectators in this latter place might not be prevented from seeing the performances. All the seats on which the spectators sat, beyond the *orchestra*, had their centres in a vertical line passing through the centre of curvature of the wall of the *orchestra*, and the lowest seat was elevated above the bottom of this area about one-sixth of the diameter of the area, a height great enough to prevent those spectators from mingling with the Senators. The seats rose gradually, from the lowest, towards the circumference of the Theatre, in such a way that their superior edges were in a right line making an angle of about 22½ degrees with the horizon; and, at intervals, the seats were interrupted by *præcinctiones*, or level landing-places, like the *diazomata* of the Greek Theatres.

From the *orchestra* to the first præcinction were fourteen seats, which were allotted to persons of the Equestrian Order, to the Tribunes and others of that quality; all above these were the seats of the Plebeians: a covered colonnade surrounded the seats above the upper præcinction, and formed a gallery in which Augustus appointed the women to sit. The height of the seats is recommended to be from 1.2 to 1.33 feet, and their breadth between 1.94 and 2.22 feet. The circumference of the semicircle was divided into six or eight parts, and lines being drawn to these points from the centre of the Theatre, determined the directions of the steps of ascent to the different seats of the spectators; the quadrilinear division of the seats between every two præcinctions and every two flights of steps was called a *cuneus*, from its wedge-like form; the stone seats seem to have been covered by boards or cushions. The decorations of the *scena* may be traced in the remains of the Theatre at Nismes, but more particularly in some of those in Syria and the Decapolis. They consist of various Orders of columns with broken entablatures and pediments, and afford sufficient indications that richness or ornament was consulted rather than good taste.

Behind the wall of the *scena* were apartments for the performers, and from these apartments there were entrances to the *pulpitum* by three doors, of which that in the centre was called the Regal door, and those on the sides were called the Hospitalian doors. The rectilinear side of the Theatre, on the exterior, was provided with a grand portico or colonnade extending the whole length of the building.

The Flavian Amphitheatre.

The history and construction of AMPHITHEATRES having been given under that word in our *Miscellaneous Division*, it will be unnecessary to enter into many details concerning those edifices; we, therefore, confine ourselves to a general description of the plans and Architectural embellishments of the principal buildings of this kind which still exist. Of these the Flavian Amphitheatre, or the Colosseum, being the most considerable, has the first claim to our attention. The form is that of an ellipse covering about five acres of ground, and the whole edifice stands on a basement to which there is an ascent by six steps extending along its whole circumference. In the centre was the *arena*, so called from the sand with which it was strewed, the lengths of whose transverse and conjugate axes were respectively 281 and 176 feet. This was surrounded by an elliptical wall which supported the *podium* or fence above. Behind this wall was a row of cells, which continued along its whole circumference, and served to contain the beasts preparatory to their entrance into the *arena*, which entrance was made by passages cut at intervals through the wall of the *podium*. Between these passages were niches in which, probably, the combatants deposited their arms and dresses previously to engaging. In rear of the cells was a corridor, from which proceeded vaults, in directions nearly perpendicular to the curvature of the ellipse, and serving to support the first *menianum*, or the interior range of seats. In some of these vaults were the steps which led to the *podium*, and others were, simply, passages between the first and the next corridor towards the exterior. This corridor received light from apertures cut in its vault through the præcinction which separated the first horizontal division of the seats from the second. In rear of this second corridor were, also, vaults in directions nearly perpendicular to the curvature of the ellipse, in some of which were steps leading to the second division of the seats, and others were galleries leading from the corridor to the double arcade which surrounded the whole edifice. The transverse axis of the exterior ellipse is 615½ feet, and the conjugate 510 feet.

On the Northern side of the building was the lodge of the Emperor, and under it were apartments in which he gave private audiences; from these apartments a colonnade led to the Imperial Palace on the Esquiline. On the Eastern and Western extremities were the doorways by which the combatants entered, or by which the dead were conveyed away.

On the exterior of the building, about its whole circumference, there are three Orders of columns, and one of pilasters, all of equal diameter and disposed in tiers one above another; and the circumference of the wall, in each tier, is perforated by eighty semicircular-headed arches ornamented with archivolt mouldings: four of the arches in the lower Order, or tier, were for the admission of distinguished personages, and the others for the populace; these were called *vomitoria*, and from them the spectators ascended to their places by steps under the vaults which supported the seats. The piers supporting the arches are 7.329 feet wide, and each is ornamented with a half-column projecting from the wall; the distance between the piers is 14.302 feet. Horizontal mouldings at the imposts, or springing of the arches, ornament the wall and entirely surround it, except where they are interrupted by the arches and columns. A plan and elevation of this edifice is given in pl. xii.

Description of the columns.

The columns in the lower tier are of an Order resembling the Doric, but they have bases, and there are neither triglyphs in the frize nor mutules in the cornice. According to the dimensions given by Degodetz, their height is 27.631 feet, and the lower diameter 2.91 feet; consequently they are about nine diameters high, and they have a very small diminution. The base consists of a plinth, a torus, and an inverted cima recta with a fillet between the two latter; the shaft is plain and the capital consists of an ovolo, the section of which is in the form of a quadrant of a circle, with a small cima reversa at its foot. The architrave is divided horizontally into three faciæ, the frize is plain, and below the corona is a band on which a row of dentels may be supposed to have been intended; the height of the entablature is 6.644 feet; consequently the height of the whole Order, above the pavement, is 34.275 feet. For an elevation of one of these columns see pl. x. fig. 2.

The second tier of columns is of the Ionic Order, and stands on a continuous stylobata, 6 feet high, the face of which is in the same plane as that of the piers, except where it is broken under each column to form a projection, like the face of a pedestal. The height of the column is 25.731 feet; the bases are of the Attic kind, the shafts are plain, and the faces of the volutes without ornament, the eye only being marked by a circle. The height of the entablature is 6.636 feet, and its subdivisions are exactly similar to those of the entablature of the Doric Order below; the faciæ of the architrave incline inward at their tops; the cornice is without modillons, and the dentel band is uncut. The entire height of this Order, including the pedestal, is 38.367 feet.

The third tier of columns is of the Corinthian Order, and, like the tier below, it stands on a general stylobata, the height of which is 6.396 feet. The height of the columns is 25.584 feet; the bases are of the Tuscan kind, consisting of a simple torus and fillet above the plinth, and the leaves in the capitals are quite plain. The height of the entablature is 6.596 feet, and its members exactly resemble those of the two lower Orders, except that the place of the corona is occupied by a row of simple modillons which support the cymatium above. The entire height of this Order, including the pedestal, is 38.576 feet.

The fourth tier consists of Corinthian pilasters which stand upon blocks 2.788 feet high, placed above a general stylobata 7 feet high. The height of the pilasters is 27.99 feet, and they are without diminution; the bases are Attic, and the capitals are exactly like those in the Order immediately below. The height of the entablature is 7.369 feet, but it is not continuous; over the capital of each pilaster is a portion of an architrave, and above it is placed a large corbel; and in the interval between every two pilasters are placed two similar corbels in the same horizontal plane, and all at distances from each other equal to one-quarter of their length in the direction of the circumference of the building. These support a continuous cornice which projects considerably beyond the wall; and the edifice is crowned by a plain parapet 6 feet high. By adding all the vertical dimensions together, we find that the whole height of the Amphitheatre, above the steps, is 162 feet.

All the columns in the three Orders have the exterior faces of their shafts projecting from the wall, in each tier, about three-quarters of a diameter. Between the columns are semicircular-headed apertures whose breadths, though some differ considerably from others, are, in general, equal to 14.479 feet, and the breadths of the piers are 7.883 feet. The faces of the walls in the different tiers are not in the same vertical plane, but each upper face recedes a little from that immediately below it, towards the interior; and the axes of those columns which are in the same vertical planes, consequently, do not fall in the same vertical lines. The thickness of the piers is also different in the three lower tiers; reckoning from the bottom of the building upward, they are, respectively, 8.706 feet, 8.377 feet, and 7.284 feet. The arches spring from imposts and are ornamented with archivolt mouldings. The lower parts of the apertures coincide with the tops of the stylobatæ, and these seem to have been intended as parapets, since they are of a height just sufficient to be leaned over for the prevention of accidents. Between every two pilasters in the fourth Order is a square window, and between every two corbels are holes left in which were placed the beams intended to support poles carrying the canvass cover, which was occasionally drawn over the building to screen the spectators from the Sun or rain. The cloth was attached to the building round its circumference, and declined towards the interior, so that the rain might fall into the *arena* by the aperture which it left in the centre.

The magnitude and distribution of the parts of this building are such as to cause it to form an imposing spectacle, notwithstanding many defects which a critical eye may discover in it. It may be justly objected to it that the three entablatures are nearly alike, though the columns are of different Orders. And it has been observed that the dimensions of the arches and piers and the projections of the members are very irregular, which seems to indicate great precipitancy in the execution.

Amph tre at Vero

The Amphitheatre at Verona, though smaller than the Colosseum, has the advantage of being in a better state of preservation. It is of an elliptical form, 508 feet long and 403 feet broad, and the dispositions of the vaults and seats are similar to those of the Colosseum. The exterior wall of the edifice is ornamented with three tiers of Tuscan pilasters projecting before the faces of the walls, and those of the two upper tiers stand upon continuous podia; between the pilasters in each tier are semicircular-headed apertures.

The horizontal joints of the stonework in the face of the wall are marked by channels, which are also carried across the faces of the pilasters. This species of ornament, if it may be so called, has subsequently been denominated rustication. At Capua, Otricoli, and Nismes are the remains of large Amphitheatres, but as a great sameness reigns in all the works of this kind, it will be unnecessary to describe them.

Naum

Naumachiæ were buildings similar to Amphitheatres, and used for the exhibition of naval combats; the *arena* being filled with water from some river, or from reservoirs communicating with it. Those of Augustus and of Domitian are said to have been the most magnificent of these buildings, but no traces remain of them.

A Circus is a building in some respects similar to an Amphitheatre, and was generally employed for the exhibition of chariot-races. It has already been described at length (CIRCUS) in our *Miscellaneous Division*, and, therefore, it will be sufficient to state the dimensions of one or two of those edifices whose foundations, which are all that remain of them, afford the means of tracing their plans with tolerable accuracy.

The *Circus Maximus*, which is supposed to have been, originally, constructed in a rude manner by Romulus, and subsequently rebuilt by the elder Tarquin, was about 2000 feet long, and 550 feet broad on the exterior, and consisted of two parallel walls in the direction of its length, which were united by a semicircle at one extremity; the other was closed by a row of vaults disposed, side by side, in a segment of a circle, the radius of which was equal to about 430 feet. These, which were called *carceres*, were to contain the chariots previous to their starting for the race; the chord of the arc was not perpendicular to the long sides of the building, but inclined to them at an angle of about 85 degrees, and at each extremity was a square tower. In the middle of the *arena*, and parallel to its length, was the *spina*, a low wall 1300 feet long, beginning near the centre of the semicircular extremity of the building; and at each end was a *meta* or goal. The seats of the spectators were disposed in inclined planes within the walls, like those of a Theatre, with a *podium* in front; and between the *podium* and *spina*, on each side of the latter, was the course for the chariots.

The Circus of Nero was of the same form nearly as that above-mentioned; its length was 1400 feet, and breadth 260 feet; the *spina* was about 800 feet long, and the *carceres* seem to have been contained in a rectangular building.

The Circus of Caracalla was of nearly the same dimensions as that of Nero, but the two sidewalls were not exactly parallel to each other, probably on account of some local impediment. One of the sides was broken, near the middle of its length, and the two parts made, with each other, a very obtuse angle. The *spina* was not parallel to either of the sides; but, at the end next to the semicircle, it was further from the straight wall by about ten feet than at the other end. The *carceres* consisted of a row of vaults like those of the great Circus, and the chord of the segmental arc made an angle of 80 degrees with one of the long walls. The radius of curvature of this arc was equal to about 330 feet.

The Hippodrome, at Constantinople, is a building of this nature, and it, probably, remains now nearly as it stood when first constructed by Constantine.

From these descriptions we perceive that the plan of the Circus was nearly in the form of a parallelogram, the exterior length of which seems to have been equal to four or five times the breadth. A high wall surrounded the ranges of seats, and was, no doubt, pierced by semicircular-headed arcades, like those in the exterior wall of a Theatre. The length of the *spina* was equal to about two-thirds of the whole interior length of the building; this was ornamented with obelisks and statues, placed above it, and was terminated at each extremity by a *meta*, consisting of three columns, or obelisks, on pedestals. The *carceres* were, generally, vaulted chambers closed in front and rear by gates; in these the chariots remained till the signal was given for driving them round the *arena*. The oblique disposition of the plan of the *carceres*, and, sometimes, of the *spina* itself, was, no doubt, intended to equalize the spaces which all the chariots were to describe, from their place of starting to the goal.

General distribution of the Roman Baths.

The *Thermæ*, or Baths, were public buildings in which the citizens, who had not conveniences for bathing in their private houses, could assemble and enjoy that luxury. They contained a suite of apartments for men, adapted to the several circumstances attending the performance of that operation among the Ancients, and a corresponding suite for women. Some remains of the public Baths of Nero, Vespasian, Titus, Caracalla, Dioclesian, and Constantine are still in existence at Rome. Those buildings were generally of a rectangular form; each was surrounded by a *peribolus* or enclosure, and contained all the different apartments for bathing; peristyles and arcades, for the purpose of promenading; *xysti*, for the exercises of the *athletæ;* Theatres; *exedræ*, or apartments for conversation; and Temples, either in the *peribolus* or in the wings of the building.

In the restorations, given by Palladio, of these edifices, we find apartments open towards the exterior, in the fronts of which are rows of columns supporting horizontal entablatures; the open fronts terminate at the roof in segmental arches with low pediments above them, and without a horizontal cornice. He supposes the *xysti* to be covered by groined vaultings, the middle of the interior peristyles and arcades to be without roofs, and the galleries, between the columns or piers and the walls, to be covered by hemicylindrical vaults.

Baths of Dioclesian.

But the Baths which exist in the best state of preservation are those of Dioclesian, which seem to have been also the most extensive and magnificent in Rome. They form a rectangle 744 feet long, and 454 feet wide, and were surrounded by a *peribolus* 1050 feet long, and 908 feet wide. In various places about this enclosure were supposed to be *exedræ* of a semicircular form, besides small rectangular Temples; and, in the middle of the longest side, a semicircular Theatre.

In the front of the building is an open court, 300 feet long, and 170 feet wide, on the right and left of which are vestibules, open towards the court and covered with groined vaultings; these lead, on each side, into a saloon supposed to have been intended for the distribution of prizes, and to the Baths for the use of those persons who did not exercise in the *xystus*. In the centre of the front, opposite the open side of the court, was the grand entrance which led to the *xystus*, a rectangular space 176 feet long, 73½ feet wide, and 90 feet high, and covered by three groined vaults supported by Corinthian columns. On the right and left of this were apartments for the spectators, vaulted in the same manner, and beyond these, on each wing, was a magnificent peristyle 229 feet long, and 114 feet wide; the surrounding galleries were roofed by semicircular-arched vaults; and at the extremities of the galleries were *ephebei*, or large apartments, open towards the peristyles.

On the side of the *xystus* opposite the grand entrance are doors leading to a circular building, which might have served as an *apodyterium;* it is 62 feet diameter, with a rectangular recess on each side; and beyond this building were the baths of the *athletæ*, in a rectangular saloon, 148 feet long, and 68 feet wide, covered with a groined vaulting. Where the apartments open into each other, the aperture is occupied by four columns, or two columns and two pilasters, and the entablature over the two middle columns is in the form of a semicircular arch. In the walls of the *xystus* are semicircular or rectangular niches, between which are columns supported on corbels projecting from the walls.

We have given, from Chambray's *Parallel of the Orders of Architecture*, an elevation of a Doric column said to have belonged to these Baths. Its height is equal to eight diameters, and the principal moulding in the capital differs from that in all the older examples of the Doric Order, in having the form of a cymatium, and below it is an astragal sculptured in the form of a rope; the cornice has no mutules, but contains a row of dentels between two curvilinear mouldings, of which the upper one is cut to resemble a bundle of leaves. See pl. x. fig. 3.

In the grand Saloon, which has been since converted into a Church by M. Angelo, the columns are of the Composite Order, and an elevation of one is given at fig. 7. pl. xi. The height of the column is 45.182 feet, and the lower diameter is 4.619 feet. The architrave is divided into three faciæ separated by sculptured mouldings, and the upper extremities of all the faciæ incline towards the interior; the cornice contains both dentels and modillons, and both the corona and the cymatium above it are richly sculptured. The height of the whole entablature is 10.725 feet, or about one-quarter of the height of the column.

General construction of the Roman Baths.

In constructing the bathing apartments, a floor of tiles seems to have been laid on the ground; on this floor were placed pillars of brick, about two feet high, at intervals, and above them was laid another floor of tiles; between these floors, under the place where the water was heated, a fire was made, and this part seems to be that which was called the *hypocaustum* or furnace; the heat from this extended itself under the floors of the different apartments which were intended to be warmed. Above the *hypocaustum* were placed three vessels, one, called *frigidarium*, contained the cold water which came from the reservoir; another, called *tepidarium*, received the water which flowed through a pipe from the former vessel, and in it the water received a certain degree of heat; the third, called *calidarium*, received the water from the *tepidarium* by a pipe, and in it the water acquired the greatest heat; from hence a pipe conveyed the hot water to the Bath.

One apartment for each sex was allotted for undressing, and called *apodyterium*. Another, called the *unctuarium*, contained the oils and ointments; and in this the people anointed themselves. Two apartments were occupied by the hot and cold Baths, and sometimes there was another apartment containing a small bathing-vessel, perhaps for children. Near the hot Bath was a warm room, called *sudatorium*, for promoting perspiration after bathing; and another, called *tepidarium*, which served as a drying room, and as a place for exercise before going into the open air; besides these, there was a grand Saloon, called *ephebeum*, for exercise and conversation.

In the floor of the *sudatorium* there seems to have been an aperture through which the heat issued from the *hypocaustum*: it was covered by a *clypeus*, or dome-shaped vessel, which might be raised or lowered at pleasure, in order to regulate the degree of heat in the room. This aperture, with its cover, was called *laconicum*, and it was probably invented by the Lacedæmonians.

The apartments just mentioned are recommended by Vitruvius to be sheltered from the Northern and North-Eastern quarters of the heavens, and the hot Baths to be placed on the South-Western side; a disposition which is found to exist in such remains of the ancient Baths as have been discovered. In those at Baden, the *baptisteria* or bathing-places are of a rectangular form, about 27 feet long, and 19 feet wide, and are excavated in the floor to the depth of 4 feet: at either end were four steps, each 1 foot high, by which the bathers descended, and on each of the long sides there were two steps, 2 feet high. The rule given by Vitruvius is, that the breadth of the basin should be two-thirds of its length, and that there should be a passage not less than 6 feet wide between the basin and the wall, that there might be room for those persons to stand who were waiting for their turn to descend into the water; he mentions a *pulvinum* about the Bath, which was, probably, a coping surrounding the basin.

In their Baths the Romans seem to have indulged an unlimited taste for magnificence; they employed, in them, the most ornamental of the Orders of Architecture, which they covered with the richest sculpture, and they adorned the walls and ceilings with splendid paintings. But, however, much as these edifices exceeded the ancient buildings of Greece in richness of embellishment, they seem to have wanted the good taste which characterised those classical works. Unfortunately a taste for variety led to a departure from the sound principles of Art in the application of the most important members of an edifice, which was not perceived amidst the profusion of ornament employed about them; and succeeding artists, copying the general style without having the talent to execute the embellishments, produced those rude edifices which, in a later Age, prevailed so generally in Europe. In the Baths of Titus are still to be seen paintings exhibiting delineations of slender twisted columns, broken entablatures, and curvilinear pediments; and if to these we add the columns supported on corbels attached to the faces of walls, and a profusion of sculpture, in which animal figures and foliage, in the most fantastical forms, are displayed, we shall, perhaps, be led to recognise the originals of most of those extravagancies which subsequently prevailed in the Moorish and Gothic buildings, executed in what are called the Middle Ages.

Portic

Colonnades covered with roofs, and quite unconnected with any building, were often raised by the Romans to serve as public promenades; these were called by the general name of Portico, and, though none of them are now in existence, yet traces of them have been found in many of the cities of the Empire. The building at Rome which is considered as the Portico of Pompey, had, probably, a similar destination, but it is differently formed. This is a rectangular area 374 feet long, 154 feet wide, and open on all sides; it is covered by a groined vaulting which rests on square piers, and above this is a second story covered by the general roof of the building. Between the arches, on the exterior of the four sides of the building, are attached Tuscan or Doric columns supporting an entablature above the crowns of the arches. In the middle of the area, and parallel to the long sides is a wall, in each face of which

Portic
Pomp

is a row of semicircular niches; and between these, in the thickness of the wall, are several circular staircases, which led to the upper story. According to Durand, this was situated before the house of Pompey, and was one of the most delicious promenades of Rome, being ornamented with alleys of trees and fountains.

CHAPTER VI.

Characteristics of the Roman Orders of Architecture.

The proportions of the several parts of the columns and their entablatures, which form the different Orders of Architecture employed by the Romans, are to be obtained from the writings of Vitruvius, and from the several edifices remaining within the limits of the Empire; and these are chiefly such as have been already described.

propor- s of the an r.

The Tuscan Order is that which presents the greatest simplicity of character; and though it does not seem to have been much used by the Romans, and no example of an Order like that which Vitruvius calls by that name is now in existence; yet, as that ancient author has given a description of such an Order, it will not be proper entirely to omit noticing it. He makes the height of the whole column equal to seven times its diameter, including the base and capital, which are each equal to half a diameter in height; and he determines the absolute height of the column by making it equal to one-third of the breadth of the Temple for which it is destined. The upper diameter of the shaft is made equal to three-quarters of the lower; consequently, the difference of the two diameters is one-quarter of the latter, and the difference of the semidiameters is $\frac{1}{56}$ of the length of the shaft. The base consists of a plinth, the height of which is about a quarter of a diameter, and of a torus, above the plinth, with an apophygis and fillet. The plinth is remarkable for being of a circular form on the plan, the semidiameter being perhaps equal to $1\frac{1}{3}$ of that of the shaft at bottom. The profile of the torus was perhaps a semicircle, and its height may have been equal to four-fifths of the height of the plinth; one-fifth of the latter may have been the height of the fillet.

The capital consists of a rectangular abacus, an ovolo, or curvilinear moulding, the profile of which is a quadrant of a circle, an apophygis and fillet, and the hypotrachelion. The whole was divided into three equal parts, of which the abacus and ovolo were each equal to one part, the apophygis and hypotrachelion were together equal to the third; and the breadth of the abacus was equal to the lower diameter of the shaft. The word hypotrachelion being used by Vitruvius, it would seem that there must have been some member to separate it from the rest of the shaft, and perhaps this was an astragal, consisting of a small semicircular moulding with its fillet.

The architrave was laid over the columns, and this consisted of two beams of timber placed side by side, with an interval of $1\frac{1}{2}$ inch between them, that the air might circulate there, and prevent the decay which Vitruvius supposes would take place if they were put close together. Perpendicularly to the architrave were placed horizontal beams which projected beyond the faces of the building as much as one-quarter of the length of the column; and this being a much greater projection than exists in any other Order, some have supposed that there is an error in the text of the Latin author; but it is possible that this may be what he intends, for such a projection accords very well with the description he gives of the Tuscan Temples, and would afford a good shelter under the colonnade. Above these cross-beams there must have been a cornice, and the inclining rafters of the roof were placed in vertical planes over the beams. For an elevation of a Tuscan column, see pl. x. fig. 4.

The massive character of the Tuscan column, and an absence almost total of ornament, caused Sir Henry Wotton to compare it to a sturdy labourer in homely apparel; but its simplicity makes it harmonize admirably with an assemblage of low wooden buildings; and, of course, there are many situations in which it may be applied with advantage.

The Roman Doric Order.

The Doric Order seems to have been seldom employed by the Romans, and in passing through their hands, it underwent a considerable change of character; particularly, it became less massive than that which is exhibited in the Grecian examples. The rules given by Vitruvius for determining its members are probably derived from the practice of the Architects of his day, but we shall not find them accord accurately with such examples of the Order as have been measured; in fact, he himself makes a difference in the essential terms of height and thickness of the columns when applied to different buildings; in Temples he prescribes that the whole height of the column should be seven times its diameter, and, in Theatres, that it should be half a diameter more; the reason of which, he says, is, that in the former, there should reign more of majesty, and less of elegance than in the latter. In order to make the triglyphs in the frize fall into their proper places, by preserving a constant proportion between the diameter of the columns and the extent of the intercolumniations, he prescribes that, if the Temple is tetrastyle, the diameter of the columns should be $\frac{1}{14}$ of the breadth of the Temple, by which means the intercolumniations will be each equal to $3\frac{1}{3}$ diameters; if hexastyle, it should be $\frac{1}{22}$ of the breadth, by which means the intercolumniations will each be $3\frac{1}{3}$ diameters; that is to say, in both cases, the species of intercolumniation is diastyle, but the proportion must vary according to the extent of the intercolumniations. The above rule permits two triglyphs to be placed over the intervals of the columns, and causes the metopes to be rather greater in breadth than the height of the frize. The diameter of the column being regulated by such considerations, the dimensions of its members may be all determined with relation to that magnitude.

The columns of the Roman Doric Order may be considered as having no base, for Vitruvius does not describe one; and of the only remaining examples of the Order, *viz.* the columns in the lower tiers at the Theatre of Marcellus, and at the Amphitheatre of Vespasian, the former are without this member, and though the latter have it, their difference in other respects from columns possessing the essential characteristics of the Doric Order, will hardly allow us to consider them as exceptions to the rule. The Doric capital consists of an abacus, ovolo, and hypotrachelion; each of these is of the same height, and the height of the whole is equal to half the diameter of the column.

Vitruvius prescribes that the diminution of the shaft of the column, or the difference of the upper and lower diameters should be from $\frac{1}{6}$ to $\frac{1}{8}$ of the latter, according to the height of the column, which he limits between 15 and 50 feet. And if we suppose the length of the shaft to be equal to seven diameters, this will make the difference of the semidiameters equal to between $\frac{1}{84}$ and $\frac{1}{112}$ of the length of the shaft. Now in the Theatre of Marcellus, and in the Colosseum, the columns are respectively 24 and 28 feet high, yet the diminutions, when compared with the diameter, are $\frac{1}{5}$ and $\frac{1}{11}$ respectively; and when compared with the length of the shaft are $\frac{1}{70}$ and $\frac{1}{180}$ respectively. Here, since the situations of the columns are similar, while the proportions are so different, it is probable, though from the want of examples we cannot positively affirm it, that no general rule for the diminutions was followed in practice.

The entasis, or swell of the shaft, is recommended to be equal to about $\frac{1}{30}$ of the diameter; and the shaft to be channelled longitudinally, with twenty grooves forming segments of circles equal to quadrants, and intersecting each other in single edges along the column.

The height of the epistylium or architrave, including the tenia, or fillet above, is equal to half a diameter, and the face of the architrave is nearly in a vertical plane passing through the upper part of the front of the shaft. The height of the frize is three-quarters of a diameter, and the triglyphs, which extend from top to bottom of the frize, have their breadth equal to half a diameter. The metopes are generally square, that is, their breadths are equal to the height of the triglyphs. The surfaces of the metopes seem to have been intended to be in the same plane with that of the architrave, and the exterior faces of the triglyphs to project forward about $\frac{1}{20}$ of the diameter of the column. The centres of the triglyphs were exactly opposite the axes of the columns, and a space was left between the outer edge of the extreme triglyph and the angle of the frize, the breadth of which was about equal to that of half a triglyph, or to one-quarter of the diameter of the column.

Above the frize is a horizontal moulding of a rectangular form in profile and broken at intervals to form projections over the triglyphs and metopes; its height is $\frac{1}{12}$ of a diameter; but whether this is to be included in the three-quarters of a diameter given to the height of the frize, does not appear from Vitruvius, and the existing examples of the Order differ in this respect. Above this moulding comes the corona, which is a plain beam projecting nearly half a diameter beyond the face of the architrave; it rests upon a small bed-moulding in the form of a cymatium, placed on the capitals of the triglyphs, and terminates above in a similar moulding; the height of the corona, including those two mouldings, is about one-quarter of a diameter. Above the corona comes the epitithedas, or crowning member of the Order, which is in the form either of a cymatium or cavetto, and its height is about equal to that of the corona; this completes the entablature.

According to Vitruvius, the soffit, or under surface of the corona, is in an inclined plane, as if it coincided with the directions of the rafters, and there are mutules over the triglyphs and metopes as in the Greek examples; but the practice of the Romans seems to have been variable in these respects; for, in the Theatre of Marcellus, it is conformable to the method of Vitruvius, but from the fragments at Albano, it appears that the soffit of the corona, and the mutules, were in horizontal positions; and both in the Colosseum, and in the fragments found at the Baths of Dioclesian, the soffit is horizontal, and there are no mutules. The general projection of the corona beyond the axis of the column is above nine-tenths of the diameter of the column.

Compari between Grecian Roman ric Orde

In the details of this Order, Vitruvius professes to have followed the practice of the Greeks; but the character of the whole is considerably lighter than that of any Grecian example we are acquainted with, if we except those at Cora and Pompeii. The shaft of the column is more slender, and the entablature lower. In the capital, the Greek echinus is changed for the ovolo, or moulding, the section of which is a quadrant of a circle, except in the example found at the Baths of Dioclesian, where this moulding is a cymatium, which, as well as the ovolo in the capital at Albano, is ornamented with sculpture.

The Roman triglyphs differ from those of the Greeks in their projection from the axis of the columns; for the latter, except in the Temple of Apollo, and in the Portico of Philip, both in the Island of Delos, have their surfaces all in the same vertical plane with the face of the architrave; whereas, according to Vitruvius, and the existing examples, we find the former project beyond the general surface of the architrave and frize about as much as the metopes were sunk within the frize in the Grecian Order. The practice of the two people, also, further differs in the position of the triglyphs at the angles formed by the meeting of the entablatures of the front and flanks of the building; the Greeks making one side of the triglyph coincide with the extremity of the entablature, while the Romans, according to Vitruvius, made the centres of such triglyphs as well as of the others correspond with the axes of the columns, as has been said.

In the Grecian examples of this Order, we found the height of the columns, taking a mean of several, to be equal to about 5.25 diameters, and the mean height of the entablature to be nearly one-third of the height of the column. In the Roman Doric, the height of the column is about 7.5 diameters, and of the entablature one-quarter of the height of the column; or if, as in the Greek examples, we do not include the epitithedas, it will be found that the height of the Roman entablature is about one-fifth of that of the column.

The Vitruvian architrave seems rather small considering the strength required in that part of the edifice; on the other hand, the frize seems too high. In the Doric entablature of the Colosseum, the architrave is divided into three faciæ, and in the cornice of the Theatre of Marcellus there are dentels in place of mutules; these circumstances detract much from the apparent solidity of the Order; nevertheless, in the latter building, it possesses a masculine character, and this example appears to have been much imitated by the Moderns.

There is reason to believe that, occasionally, the Roman artists made use of columns which had been executed in Greece, or which had formerly belonged to Grecian edifices, and that they altered the forms of such columns to suit their own taste or convenience; it is also possible that, in some cases, during the later period of the Empire, when the intercourse between Italy and Greece had become frequent, the Roman Doric Order might affect a Grecian character. An example of a modification of the Grecian Doric occurs in some columns which are supposed to have been taken from the Baths of Dioclesian, and are now situated in the nave of the Church of S. Pietro in Vincoli. These are of

Cipoline marble; their heights are equal to 8.8 diameters, and their shafts, which begin to diminish from one-third of their heights, are ornamented with shallow flutings, like those in the Greek columns. The profile of the principal moulding in the capital, instead of being an ovolo, is nearly in the form of an inverted frustum of a cone, and appears to have been originally an echinus, but brought to this form by rubbing away its surface; the sides of the abacus have also been rubbed, so as to leave no margin between those sides and the top of the echinus. The columns have a sort of Tuscan base, consisting of a plinth and torus, which have, perhaps, been added to the original shaft.

Of the Ionic Order few examples executed by the Romans remain, but the description of it given by Vitruvius is nearly as follows. The height of the column is equal to 8.5 diameters, and it has a base and capital peculiar to itself. The height of the former, from the bottom of the plinth to the top of the upper torus, is half a diameter, and the height of the plinth is equal to one-third of that of the base. Above the plinth are two scotiæ separated from each other by a double astragal with fillets, and upon the upper scotia is placed a torus moulding, whose height is equal to that of the plinth; this must be considered as a specimen of extremely bad taste, for the massive torus, which ought to have been the lowest moulding, seems to crush those below it by its weight; happily for the credit of the Roman artists, this construction does not seem to have had many followers, and Milizia, speaking of it, says, *Ne' monumenti Romani non si è finora trovato vestigio alcuno di sì brutta base.* Instead of it we generally find that the bases of the Roman Ionic columns resemble that which is called the Attic base.

The diminution of the columns seems intended by Vitruvius to be the same as in the Doric Order, and, like it, to depend upon the height of the column. The height of the capital, reckoning from the top of the abacus to the bottom of the volutes, is equal to half a diameter, and the vertical section of the abacus is not a simple rectangle, as in the Doric Order, but has a cymatium and fillet at the top. The centre of the volute is in a vertical plane passing through the top of the front of the abacus, and in a vertical line drawn in that plane at a distance from the middle of the abacus equal to 0.489 diameter of the column. The whole height of the volute is 0.842 diameter, measured in the vertical line passing through the centre; and this line, being divided so that the ratio of the whole to the parts shall be as 1 to 0.56, and as 1 to 0.44, respectively, and the larger division, set down from the top, will give the centre of the volute; the diameter of the *cathetus*, or eye of the volute is one-eighth of the height; within this cathetus the centres are to be found for describing the several spirals, which, evidently, he supposes to be portions of circles, whereas the Greek spirals seem to have been a sort of transcendental curves. Below the abacus, at a distance equal to two diameters of the eye, is the top of an ovolo, which is sculptured with oves and arrows; the height of the ovolo is equal to two diameters of the eye, and at a distance below the ovolo, equal to one diameter of the eye, is the upper surface of an astragal which crowns the shaft, and separates it from the hypotrachelion. The projection of the top of the ovolo beyond a vertical plane passing through the top of the abacus is also equal to a diameter of the eye. The shafts of the columns are fluted with twenty-four channels of a semicircular form, and between every two is a fillet equal in breadth to the entasis of the column, that is, to about $\frac{1}{30}$ of a diameter.

The height of the epistylium or architrave is made to depend on that of the column; when the latter varies from 12 to 30 feet, the former varies from $\frac{1}{17}$ to $\frac{1}{12}$ of the height of the column; and this increase of the height of the architrave is to compensate for the apparent diminution of magnitude produced by the elevation of the object above the eye of the observer. The architrave is crowned by a cymatium, exclusive of which it is divided into three faciæ, the breadths of which, from the bottom upward, are respectively in the ratio of the numbers 3, 4, and 5; each upper face projects a little over the lower; the lowest is nearly in a vertical plane passing through the top of the exterior surface of the shaft, and the highest nearly in a vertical plane passing through the foot of that surface. The height of the frize is equal to $\frac{3}{4}$ of that of the architrave, if plain, but if sculptured it should be equal to $\frac{5}{4}$ of that member; and the frize, like the architrave, is crowned by a cymatium. The cornice is divided into three equal parts, of which the lower is occupied by the line of dentels, the middle by the corona, and the upper by the epitithedas. The height of the dentels is equal to that of the middle face of the epistylium; their projections are equal to their heights; their breadths equal to half their heights; and the intervals between them are each equal to two-thirds of their breadths. The whole height of the entablature, according to the dimensions above given, will vary from about $\frac{1}{6}$ to about $\frac{1}{4}$ of the height of the column; and Vitruvius recommends that the faces of the architrave and frize should not be in vertical planes, but should incline forward at top as much as $\frac{1}{12}$ of their height, in order to counteract the apparent receding of the upper parts of vertical objects when viewed by an eye situated below them. He makes the corona project as much as 1.131 diameter from the axis of the column, and 0.656 diameter from the face of the frize.

The comparison between the proportions assigned by Vitruvius to the principal parts of this Order, and those actually adopted by the Roman artists will be best effected by means of a Table, showing the dimensions of the only existing examples of Roman Ionic columns, which are those belonging to some of the buildings we have already described. The dimensions are in English feet, and in the height of the cornice is included that of the crowning member.

Names of Edifices.	Height of base.	Height of shaft.	Height of capital.	Lower diam.	Upper diam.	Height of architr.	Height of frize.	Height of cornice.
The Temple of Fortuna Virilis........	1.592	24.335	1.421	3.109	2.72	1.834	1.489	3.461
The Temple of Concord.............	2.243	38.375	2.243	4.486	3.701	2.12	2.65	2.43
The Theatre of Marcellus............	1.33	21.72	0.89	2.66	2.24	1.906	1.622	2.832
The Colosseum..................	1.358	23.015	1.358	2.91	2.424	2.25	1.67	2.716

From these we find that the Vitruvian column is rather less slender than those actually constructed, for a mean being taken of all, shows the height of the columns to be equal to nine diameters. In every other respect the proportions are nearly the same. The height of the capitals and bases are equal to about half a diameter. If we measure the diminution by the ratio of the difference of the upper and lower diameters of the shaft to the lower diameter, Vitruvius makes it from $\frac{1}{6}$ to $\frac{1}{8}$, and the mean diminution in practice is $\frac{1}{6.1}$; or if we measure it by the ratio of the difference of the semidiameters to the length of the shaft, his rule for columns of the same height as those in the above examples, makes the diminution equal to $\frac{1}{112}$, and in practice it seems to have been $\frac{1}{107}$ of the length of the shaft. The rules given by Vitruvius for the dimensions of the entablature make this member rather larger than it is found to be in the existing examples; since for columns of about the same heights as these, the height of his entablature is equal to 2.313 diameters, while the mean height of those in the examples is but 2.12 diameters. It may be remarked that the faciæ of the architraves in the Theatre of Marcellus, and in the Colosseum, have that inclination forward which is prescribed by Vitruvius.

Comparison between the Grecian and Roman Ionic Orders.

If we compare together the examples of the Grecian and Roman Ionic Orders, it will appear that the columns of the latter are scarcely more slender than those of the former, since their mean height is equal to nine diameters, and that of the Greek examples is 8.95 diameters. The diminution of the shafts, if we take it with relation to the diameter of the column, is nearly the same in both; but if we estimate it with respect to the length of the shaft, we shall find the diminution of the Roman columns is less than that of the Grecian; in the former it being equal to $\frac{1}{107}$, and in the latter to $\frac{1}{90}$ of the length of the shaft. The height of the entablature among both Romans and Greeks is equal to about two diameters, or to about $\frac{1}{4.3}$ of the height of the columns; but, in the Greek columns, the epitithedas is not included; now the only Roman Ionic example which we can consider in this way is the Temple of Fortuna Virilis, and if, in this entablature, we leave out the epitithedas, its height will be equal to $\frac{1}{5}$ of the height of the column; consequently, if, as is probable, there were at one time, in the Empire, many specimens of the Order similar to this, by which the general character of the Order might be determined, it would follow that the Roman Ionic entablature may be considered as much lighter than the Grecian. The height of the architrave is nearly equal to that of the frize in both the Roman and Greek examples, but there is a considerable difference in the proportion of the cornice to either of the other members. In the Roman Order the height of the cornice exceeds that of the architrave in the ratio of 1.25 to 1; and in the Grecian Order, it is only equal to $\frac{1}{2.6}$ of the height of that member.

We find a considerable difference in the capitals of the Grecian and Roman Ionic Orders; the volutes of the latter are smaller than those of the former, and consist of but one spiral baltheus which is bent down from the under side of the abacus, while the Grecian spiral is double or triple, and the curves are continued in the form of festoons on the front of the capital. The sides of the Roman capitals present the appearance of bundles of leaves bound in the middle, except in the Temple of Concord, where all the four faces are of similar forms, the planes of the volutes being situated obliquely to the sides of the abacus, instead of being in a plane parallel to its front. This disposition certainly has the advantage of producing uniformity of appearance on the four faces of the capital; but the unequal foreshortening of the spirals, which occurs when the eye is not opposite the middle of the capital, gives an irregularity to their figures, and the apparent ellipticity of their curves makes them seem disagreeably compressed.

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Of the Corinthian Order, Vitruvius gives no other account than of its origin, and the dimensions of its capital. He makes the whole height of the capital, including the abacus, equal to one diameter of the column; the plan of the abacus is not a square, but the faces of it are cut in the form of arcs of circles, concave outwards, and described upon the sides of a square the diagonal of which is equal to two diameters of the column, and the versed sine of each arc is equal to $\frac{1}{9}$ of the side of the square. The bottom of the capital has the same diameter as the top of the shaft of the column, and under it is an astragal and fillet. The height of the abacus is equal to $\frac{1}{7}$ of the diameter, and the remainder of the height of the capital is divided into three equal parts; these divisions determine the heights of the two courses of leaves, and the upper of the three spaces is appropriated to the caulicoli or stems from whence spring the volutes which curl under the angles of the abacus. We may suppose him to mean that the proportions of this Order, in other respects, should be the same as those of the Ionic Order.

The Corinthian Order may be considered as exhibiting the highest degree of refinement in Architecture; and though it is distinguished for the richness of its ornaments, yet, as a whole, it may be considered, perhaps, as the most simple of all the Orders, and admitting of greatest facility in its execution. The construction of the volutes in the capitals of the Ionic Order, and the embarrassment arising from the disposition of the triglyphs, together with the sculpture in the metopes of the Grecian Doric Order, render these more complex than the Corinthian; so that it would seem as if the ancient artists, while, in the Orders of later invention, they aimed to obtain more beauty than existed in the earlier Orders, endeavoured also to procure more simplicity and elegance. Among the Romans, the Corinthian Order became the general favourite; it seems to have entirely superseded the two more ancient Orders, and to have gone on increasing in richness of decoration till it arrived at the highest degree of luxury in the works erected by that people in Asia Minor and Syria.

It is uncertain whether or not the Greeks invented that form of capital which is so generally employed in the Roman buildings constructed according to this Order; and which is found in Greece itself, in edifices constructed by Roman or native artists at times subsequent to the Roman conquest of the Country. Be that as it may, it is to Italy, and to the different Provinces of the Empire, that we are to look for examples of the Corinthian Order, of which many remain to this day in a state of good preservation. The following Table exhibits the dimensions of columns belonging to the six principal edifices; and from them we shall be enabled to deduce the proportions which may be considered as characteristic of the Order. We have added to the Table the dimensions of the three principal examples of the Composite Order; in order to avoid making a

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Part II.

separate Table of examples the proportions of which do not differ materially from those of the former Order. The dimensions are all in English feet, and we have included the epitithedas in the height of the cornice.

Names of Edifices.	Height of base.	Height of shaft.	Height of capital.	Lower diam.	Upper diam.	Height of architr.	Height of frize.	Height of cornice.
Portico of the Pantheon	2.398	38.995	5.636	4.797	4.102	3.396	3.396	4.325
Interior of the Pantheon	1.821	29.211	3.642	3.642	3.157	2.579	2.493	3.128
Temple of Jupiter Tonans	2.325	39.391	5.368	4.598	3.99	2.772	3.189	3.553
Temple of Jupiter Stator	2.445	39.973	5.228	4.841	4.313	3.389	3.389	5.501
Façade of Nero	3.646	53.514	8.34	6.568	5.801	4.875	4.842	6.307
Arch of Constantine	1.757	23.1	3.18	2.902	2.562	2.176	1.935	2.829
Arch of Titus	2.345	17.056	2.664	2.07	1.836	1.588	1.552	2.105
Arch of Severus	1.444	23.1	3.303	2.887	2.549	2.166	1.227	3.296
Baths of Dioclesian	2.405	40.605	5.466	4.619	3.746	3.426	3.373	3.926

By a mean of the first six examples, we find the height of the Corinthian column to be equal to 9.81 diameters, a proportion rather more slender than that assigned by Vitruvius, (ch. i. book iv.) who makes the height equal to 9$\frac{1}{6}$ diameters The mean height of the base is equal to 0 527 diameter, and of the capital, is 1.135 diameter. The diminution, or difference of the upper and lower diameters is $\frac{1}{8}$ of the latter, and the difference of the semidiameters is $\frac{1}{140}$ of the length of the shaft. The height of the whole entablature is equal to 2.296 diameters; that is to $\frac{1}{4.3}$ of the height of the column. The heights of the architrave and frize are nearly equal to each other, and each is equal to 0.667 diameter; and the height of the cornice is equal to 0.962 diameter. So that while the proportions of the Corinthian shaft and base remain the same, nearly, as in the Ionic Order, the height of the capital is twice as great. The proportions of the architrave, frize, and cornice to each other, and to the diameter of the column, remain also nearly the same as in the Ionic Order. The projection of the corona from the axis of the column is equal to 1.226 diameter, and from the frize is 0.749 diameter.

The Attic base is sometimes employed in the Corinthian Order, but, frequently, it consists of two tori, having two scotiæ between them separated from each other by a double astragal and fillets, and the whole supported on a square plinth, the projection of which from the axis of the column is, by a mean of the above examples, equal to 0.695 diameter.

The generality of the capitals in this Order consist of a bell-shaped vase surrounded by two rows of foliage, one above the other, the upper row springing from the intervals of the lower; and from the intervals of the upper row proceed cauliculi or stems, which, curling under the angles of the abacus, form small volutes; each principal leaf is composed of clusters of small leaves resembling those of the olive, and the bases of the shoots which form the volutes are ornamented with the same kind of foliage.

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It is in the entablature of the Corinthian Order that the Roman artists have deviated most considerably from Nature and from the practice of their Grecian masters, and even from the precepts of Vitruvius. In the cornices of all the Roman examples of the Order we find both modillons and dentels employed, and the former are invariably placed above the others; whereas if the modillons represent the ends of the principal rafters, and the dentels those of the smaller, the latter should have been placed above the others; it is true that the dentels would not be seen to advantage by an eye near the ground if they were placed above the modillons, but there is no reason why one or the other of them should not be omitted; and to retain both, thus misapplied, is a sacrifice of good taste to ostentation. The modillons are sometimes of a rectangular figure, or are divided into two faciæ, as in the entablature of Nero; but, in almost every case, their under-surfaces are cut in the form of a scroll or curve of contrary flexure, the thicker extremity of the member being nearest to the face of the cornice in which they are inserted. Under this inferior surface is attached a piece of sculpture in the form of a leaf, and the profiles of the modillon represent the curve continued and forming a spiral ornament. There are some examples, as the entablature of the Maison Quarrée at Nismes, and even the interior cornice of the Temple of the Winds at Athens, in which the smaller end of the modillons is placed next to the wall; but it is evident that this disposition is improper, since it takes away from the member its essential character, which is that of a support to the corona, and makes itself appear to want support.

It has been said, in describing the Pantheon at Rome, that on the interior surface of the cylindrical wall, the vertical sides of the modillons and the corresponding sides of the lacunaria or coffers in the soffit of the corona, instead of being parallel to each other, tend towards the axis of the building; by this circumstance the symmetry of the work is preserved, while no rule of propriety is violated in consequence of one extremity of the modillon being smaller than the other, since the larger end is that next to the wall, which is the place wherein the greatest strength is required. But on the convex exterior of the same building, the vertical sides are made parallel to each other, in order, no doubt, to avoid the bad effect which would have been produced by making the outer extremity broader than the other, and thereby giving to the modillon an appearance of weakness.

The magnitude and disposition of the dentels and modillons in Roman Architecture follow no general rules; by taking a mean of the dimensions of these members in several buildings, we find, for the dentels, the height equal to 0.158 diameter of the column; the breadth equal to 0.119 diameter; the projection, 0.141 diameter; and the interval of every two, 0.053 diameter, or about half the breadth: for the modillons, the height 0.156 diameter; the breadth, 0.192 diameter; the length, 0.344 diameter; and the interval of every two, 0.428 diameter. In some examples the centre of a dentel or modillon corresponds nearly with the axis of the column; in others one of the vertical sides corresponds with it; and there are again others in which the middle of the interval falls in that position. It is evident, therefore, that convenience only has been attended to in disposing those ornaments.

The Composite Order.

The Composite Order differs so little from that which has been just described, that it can hardly be considered as entitled to a distinct appellation. In the Arches of

Titus and Septimius Severus, which are the principal examples of the Order, if it may be so called, the profiles of the entablature and of the base of the column as much resemble some of those of the Corinthian Order, as many examples of the latter resemble each other; and, perhaps, the writers on Architecture are no more justified in treating this as a fifth Order, on account of its capital, than they would be in considering as so many different Orders, all the columns made subsequently with capitals which are not exactly identical. It must be observed that the Composite columns in the Baths of Dioclesian are remarkable for as great a diminution as is found in many of the Grecian Doric columns, the difference of the diameters being equal to $\frac{1}{5.3}$ of the lower, and the difference of the semidiameters, to $\frac{1}{86}$ of the length of the shaft.

When the Triumphal Arches were first noticed, at the time of the revival of learning, on account of the Historical subjects sculptured on them, the capitals of the two above-mentioned were observed to be compounded of the leaves of the Corinthian, and of the volutes of the Ionic Orders; and this seems to have induced Scamozzi to consider them as appertaining to an Order distinct from either of the other four. The Composite capital consists of two rows of leaves surrounding a bell-shaped vase; the stems of the leaves of the interior row rise in the intervals of the leaves of the lower row, and the tops of the former leaves are as much above those of the latter, as these are above the bottom of the vase. The foliage is richer than that of the Corinthian Order in general, and seems composed of leaves of the acanthus. Above the upper row is an ovolo moulding which resembles the exterior of a shallow vase, and from this vase, about the middle of the face of the capital, spring two stems which diverge to the right and left and form large volutes diagonally under the angles of the abacus.

This kind of capital, which may be said to have a greater appearance of strength and even less of elegance than the Corinthian, has been employed chiefly on the columns which adorn the Triumphal Arches of Italy; and Serlio supposes that the Romans used it to express their dominion over the people who invented the Orders of which it is composed.

In the Roman Architecture, when columns are attached to the walls of buildings, the entablature, as we have seen, is frequently broken so as to make it project over each column; this practice is generally condemned, because it is said to be inconsistent with the intention of an entablature, which is to express a continuous line of beams resting on the columns. It would be easy, however, to find a prototype for such a mode of construction; for the projecting parts of the entablature may represent the extremities of beams supposed to be situated perpendicularly to, and carried out beyond the face of the building.

Irregularities in the proportions of the Orders.

In comparing the different Orders of Architecture together, and contemplating the different examples of each Order, we cannot avoid observing that the Ancients did not bind themselves to any constant proportions between the parts of an Order, but, perhaps, made them depend upon the situation or destination of the edifices. In the Ist Chapter of the IVth Book, Vitruvius, describing the Orders separately, makes the height of the Doric columns equal to seven times their diameter; the height of the Ionic columns equal to 8½ diameters; and of the Corinthian to 9½ diameters. But in speaking of the intercolumniations, (book iii. chap. ii.) he states, that in aræostyle Temples, the height of the columns should be equal to 8 diameters; in the diastyle and eustyle, it should be 8½ diameters; in the systyle, it should be 9½ diameters; and in the pycnostyle, it should be 10 diameters; and these proportions are given without any regard to the particular Order employed. He thus makes the proportion of the diameter to the height of the column depend upon the intercolumniation, a circumstance which was, perhaps, not attended to by the Greeks. Again, the proportions are made to differ according to the character of the building; the columns which ornament a Theatre being more slender than those of the same Order which surround a Temple.

Finally, the diminutions of the columns of the Roman Orders, like those of the Grecian, are subject to great irregularities if we compare the individual examples; thus a column 34 feet high has the same diminution as one 47 feet high; a column 24 feet high has the same as another of 34 feet; and a column which is 47 feet high has less diminution than one which is 65 feet high, contrary to the general rule which gives to the taller column less diminution than to the shorter one. But on taking the mean diminutions of columns belonging to the different Orders, we find that the Doric columns are more diminished than the Ionic, and these more than the Corinthian; from which circumstance we are disposed to conclude that the degree of diminution was made to depend, not upon the absolute height of the shaft, but upon the proportion that the diameter of the column bore to its height; and that this rule was subject to great modifications, with the causes of which we are not well acquainted.

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It seems as if Vitruvius intended the general proportion between the diameter and height of a column to be employed only when the intercolumniation, or distance between the nearest parts of the surfaces of two columns, is of the kind called pycnostyle; for, in the IId Chapter of the IIId Book, he proposes, when the intercolumniation is increased, to augment the thickness of the columns, so much as from $\frac{1}{10}$ to $\frac{1}{8}$ of the diameter of the column, in passing from the pycnostyle to the aræostyle. Now, we are probably to understand that the intercolumniation is to be regulated by the augmented diameter, and not by the original diameter of the column; for, in the former case only, will the ratio between the diameter and the interval be that which is prescribed by the rule of the intended intercolumniation. This may be easily perceived; for in the aræostyle intercolumniation, the ratio of the diameter to the interval may be as 1 to 4; and by augmenting the diameter, retaining the same distance between the centres of the columns, the ratio will become as 1 to 3.5 nearly, which would reduce the intercolumniation to the diastyle kind nearly, and render the rule of the aræostyle intercolumniation useless. This could not have been the intention of Vitruvius, and it is probable, therefore, that he meant to increase the diameter of the column, in order to give it such additional strength that the intercolumniation might be made equal to four diameters without danger. Sir William Chambers objects to this rule of Vitruvius that it does not answer the intention, since the diameter and intercolumniation are both increased in the same proportion; the objection, however, only applies to the apparent strength, for the intercolumniations are proportional to the diameters of the columns simply, while the real strength of the columns in supporting incumbent weights, are proportional to the squares of their diameters, which is a higher ratio than the former, as that author admits. (See Gwilt's edition of Sir W. Chambers's *Architecture*, vol. ii. p. 268.) A more serious defect would arise from the increase of the intercolumniations, *viz.* that the architrave over the interval would become weaker, and, in order to remedy this evil, it would be necessary to give proportional thickness to that part of the entablature.

It is probable, as Sir W. Chambers supposes, that Vitruvius intended the five intercolumniations mentioned in his IIId Book, to be applied only to the Ionic and Corinthian Orders, which, according to him, differ only in their capitals; for, in the IIId and VIIth Chapters of the IVth Book, he establishes other intervals for the Tuscan and Doric Orders, regulating the latter by the triglyphs, of which there were generally two over each intercolumniation; the monotriglyph and aræostyle interval being only used in cases of necessity.

A regard to the first principles of Architecture would lead us to suppose that, in the same story of a building all the columns should be of equal height; but the inequality of the ground, or the different levels of the parts of the roof have prevented the Ancients from adhering always to this rule. Pedestals were resorted to in order to correct the former inequality, and bring the bases of all the columns on the same floor to the same horizontal plane, but no remedy could be found for the other, and the columns were made of different heights.

In the Propyleum at Athens, the columns of the exterior portico are lower than those in the vestibule; the former are of the Doric, and the latter of the Ionic Order. In the ruins of Balbec there is a contrary example, for the columns in the front of the portico are higher than those within; and a remarkable case, in which the entablature of a line of columns has been made to rest, at one extremity, on a corbel attached to the shaft of a higher column, has been mentioned in speaking of the ruins in the Decapolis.

CHAPTER VII.

General Description of the other Ornamental Parts of Roman Edifices.

The employment of pilasters in the buildings of the Romans was very general, and specimens of them may be seen in the Pantheon, the Temple of Mars the Avenger, the Baths of Dioclesian, and other works; sometimes they were attached to the faces of walls, and projected but a little way from them, as in the interior face of the first-mentioned building; but at other times they formed a sort of square column, having the same kind of bases and capitals, and having the diminutions of their shafts and all their other proportions nearly identical with those of the round columns which belong to the same Order, as in the porticos of the Pantheon and of Mars the Avenger.

In these buildings the pilasters are of the Corinthian Order; of the Ionic Order, the Baths of Dioclesian afford one example. The height of this pilaster is equal to 8.5 times its breadth; the shaft is made without diminution contrary to the general practice, and each face is furrowed by five channels with vertical fillets between them; between the volutes of the capital the plan of the ovolo forms an arc of a circle, and this member is sculptured with oves and darts as usual; the base and capital are each equal in height to about half a diameter, and the former is of the Attic kind. The height of the whole entablature is equal to 1.8 times the breadth of the pilaster, or to $\frac{1}{4.72}$ of its height. The architrave is divided into three faciæ, the frize is swelled in a cylindrical form, and there are dentels in the cornice. The Greek antæ differed from the Roman pilasters in being always placed at the extremities of walls, from which they projected but little, in having no diminution of shaft, and mouldings quite different from those of the columns with which they were connected in the same building.

Pedestals.

In the ancient Grecian Architecture, pedestals were not employed as supports of columns, but in Roman Architecture they enter as an important feature and were often highly embellished. The principal part of a pedestal is a dado or die, in the form of a rectangular parallelopiped, and either plain or ornamented with sculpture; this is crowned by a cornice consisting of an alternation of plain faciæ and curvilinear mouldings, generally cymatia; and under it is a base composed, in most cases, of a torus moulding with an inverted cymatium above; the whole rests upon a plain plinth. The mouldings both of the base and cornice are more numerous in proportion to the richness of the Order, though this rule is not universal; in the Arch of Severus, for example, the dados of the pedestals are plain and the mouldings are few, though the columns are of the Composite Order.

The dimensions of the Roman pedestals are various, but, by taking a mean of those employed in the Triumphal Arches, we find the height of the dado to be equal to 2.41 diameters of the column, and its breadth, 1.41 diameter, or nearly the same as the length of each side of the plinth of the column. The height of the cornice is 0.45 diameter, and its projection from the face of the dado, 0.35 diameter. The height of the base, not including the plinth, is 0.5 diameter, and its projection 0.41 diameter; and when the plinth rests immediately on the ground, its height is equal to about half a diameter; so that the whole height of the pedestal, in the Roman examples, may be considered equal to 3.86 diameters, or to more than one-third of the height of the column.

A stylobata is a sort of general pedestal serving for the support of a whole range of columns, and its profile is the same as that of a single pedestal; under each column in the range the stylobata is generally broken so that its face projects a little forward, and this gives to the whole the appearance of a number of pedestals connected together by low walls.

Equal attention seems to have been paid by the Ancients to the apparent form of a stylobata and of the shafts of columns; for Vitruvius directs (book iii. ch. iii.) that the upper surface of the former should be raised higher in the middle than at the extremities, in order to correct the optical deception which causes a long line, when perfectly horizontal, to appear lowest in the middle, as it causes the sides of a conical shaft to assume a concave figure. Small pedestals were sometimes placed over the walls, one at each angle of a building, with their upper surfaces above the sloping sides of the roof; and a similar one on the apex of the pediment; these, which were called *acroteria*, were probably intended for the support of statues; they were ornamented with a moulding above, and Vitruvius prescribes that the tops of those at the angles should be in a horizontal plane passing through the middle of the tympanum, and that the height of the acroterion at the vertex should exceed that of the others by about one-eighth.

Arches. The arches built by the Romans, both for their bridges and to serve as apertures in buildings erected on land, were almost invariably semicircular, and were formed either of plain voussoirs, as in the Theatre of Marcellus; or, as in the arcades of the Colosseum, the exterior front of the arch was divided into faciæ, and ornamented with mouldings resembling those on the horizontal architrave of a building, and hence called an archivolt. The arches which cover the apertures in Roman works are, in almost every case, made to rise from the upper surface of a sort of cornice, or impost, in the wall on each side; but, in the decline of Art, we find that some ill-founded perception of beauty, or some vain attempt to excite admiration by an appearance of boldness, led to the practice of making them spring from the capitals of columns, or from the extremities of the horizontal entablature placed over a colonnade, the entablature being interrupted under the arch. Such caprices exist in the Architecture of the Roman Baths and in the Palace of Dioclesian; from whence they were copied in the edifices of Europe in later times, and became the origin of a style unknown to the ancient artists of Greece and Rome.

In the later Ages of the Empire, when small and slender columns were employed for the support of arches, a practice arose of increasing the projection of the capitals in order to afford room for the foot of the archivolt on each side: and the intrados of the latter coming over the lateral extremity of the capital caused the breadth of the aperture to be less than the intercolumniation; and this is one of the distinguishing features of the arcades in the Ecclesiastical edifices of the time of Constantine, and in the buildings derived from them.

In the Theatres and Amphitheatres of the Romans, and in their Triumphal Monuments, the arches are important features; and by taking a mean of the dimensions in several examples, we find that the proportion between the height and breadth of an aperture covered in this manner is nearly as two to one; consequently the height of the top of the impost from the foot of the aperture is equal to three-fourths of the height of the whole aperture. The intrados and extrados of the voussoirs of an arch were originally made concentric with each other, but it has been observed that after the time of Vespasian, the voussoir at the foot of the arch was frequently made the longest, and the others diminished in length gradually to that at the vertex. Where great weight was to be supported several courses of voussoirs were placed one above another, and their joints, in all the courses, united in lines tending to the centre of the arch.

Impost. An impost, we have said, is a sort of cornice forming the ornament of the tops of piers which are connected by arches, and resembling, generally, the crowning member of a pedestal. At a small distance below the mouldings of the impost is an astragal and fillet, the interval between which and the lowest part of the mouldings is frequently plain, but sometimes it is ornamented with sculpture, and constitutes a sort of hypotrachelion; these mouldings give to the whole pier the appearance of a broad pilaster of which the impost is the capital.

The impost of the great Arch of Constantine has a corona with modillons and dentels, like the regular cornice of a building; and that of the great Arch of Severus is ornamented with dentels, but has no modillons. By a mean of the dimensions, in several examples, it appears that the height of all the mouldings of the impost, including the hypotrachelion, is $\frac{1}{11}$ of the span of the arch, or $\frac{1}{16}$ of the height of the pier, and the projection of its upper moulding is $\frac{1}{13}$ of the same span. When the piers of an arcade are ornamented with attached columns, the projection of the imposts from the face of the wall is not permitted to exceed that of the centres of the columns, lest the mouldings should interfere too much with the vertical lines produced by the surfaces of the columns.

Archivol The ornaments of archivolts appear to have been derived from those of the architrave in a horizontal entablature, the fronts of the arch stones being broken into two or more concentric faciæ, and terminated at the extrados by a cymatium and fillet; and as the faciæ of an architrave in general incline forward, so also in the archivolts, the upper extremities of the faciæ project further from the face of the wall than the lower. In the Doric and Ionic Orders of the Colosseum, the divisions which separate the faciæ are plain chamfers; but in most of the Triumphal Arches those divisions are formed in mouldings, generally astragals, either cut in beads or ornamented with foliage; the cymatium above the exterior faciæ is also sculptured in a similar way. The intrados of the arch spring from a point vertically over the side of the pier; and by a mean of several examples we find the breadth of the archivolt is equal to $\frac{1}{13}$ of the span of the arch.

Pedimen In the generality of the Roman buildings we find that the height of the apex of the pediment above the top of the horizontal cornice, is one-fifth of the whole length of that cornice in the front of the building; which makes the angle of inclination of the rafters to the horizon equal to 21° 49′; in the Grecian buildings, the angle of inclination was found to be about 12° 40′. The surface of the tympanum is in a vertical plane coinciding with the face of the architrave. The corona of the inclining sides of the pediment is like that over the columns, and it is surmounted by a cymatium the height of which is nearly the same as that of the corona. This cymatium does not occur over the horizontal cornice of the pediment, but is generally continued, in Roman buildings, over the entablature of the flanks; and on this account we have, in describing the Roman Orders, included the height of the cymatium in that of the cornice: the case was different with the Grecian Orders, for in them, generally, a horizontal cymatium over the cornice of the flank of a building either had not been formed, or had been subsequently destroyed, so that its dimensions could not often be ascertained.

Dome The circular and polygonal buildings of the Greeks have been shown to be covered by roofs of solid stone; but the Roman domes are formed of bricks, or pumice stones of small dimensions; and the Pantheon is the earliest edifice of the kind of which we have any knowledge, though it is not likely that a work of such magnitude should have been the first of the kind. In building it, the lateral pressure round the base, which arises from the weight, must have been appreciated, since we find it is resisted by making the lower courses of voussoirs thicker than the others, and by disposing several horizontal courses of materials round the exterior of the foot of the dome; the mechanical conditions of its stability, also, must have been known and distinguished from those of the stability of a cylindrical vault; since an aperture is left at the vertex which, if attempted in a vault of the latter description, would have rendered it incapable of supporting itself for a moment.

The domes which serve as coverings to Roman Temples or Tombs may be considered as forming, universally, segments of spheres; yet one example remains in which a vertical section of the dome presents the appearance of two arcs of circles meeting in a point over the centre; this is the brick Temple, said to be of Proserpine, on the Lake Avernus. Its plan is octagonal on the exterior, but within, circular, and the beds of the courses forming the dome are horizontal: the figure of the latter certainly differs but little from a hemisphere, and it might be supposed that some partial sinking of the materials had given it the pointed form; but we learn that no such failure is visible, and that the work is undoubtedly of Roman execution.

es.

Niches or recesses were, generally, formed in the interior of Roman buildings, particularly of Temples and Baths; those of smaller dimensions serving to contain statues, and the greater intended as oratories, or exedræ, in which persons might retire for conversation apart from the rest of the company. In almost every case they were half-cylinders, terminated above by vaults in the form of quadrants of spheres; though, occasionally, they were rectangular on the plan, and then their covering was hemicylindrical. The decorations of recesses, when the latter were small, resembled those about doors or windows; and, when large, the principal ornaments of the interior of the building were continued or repeated within them.

led ns.

In the ruins of Palmyra have been found examples of columns coupled together, with two sides of their plinths nearly in contact, and the intervals of the pairs of columns equal to between three and four diameters. Hence it has been concluded that this practice was not unknown to the Ancients, though nothing of the kind has been found in any Grecian building; and no other ancient example of coupled columns exists, except in the Temple, called of Bacchus, at Rome; and in this building, which, as has been described, is circular, the columns are coupled in the direction of the radii. In such a situation as this, the coupled columns are not destitute of utility, because they serve for the support of a roof, and have a lighter appearance than single columns of an adequate bulk. But when columns support an entablature on the exterior of a building, the reason of coupling them must have been to gain large intervals opposite to doorways and windows; and it may have been supposed that, by so doing, equal strength might be obtained with greater extent of intercolumniation between the pairs, than single columns would afford. This, however, does not appear to be just; for, though the number of points of support may be equal whether the columns be single or double, yet, bringing some of the columns nearer together in order to increase the intervals of others, will cause the entablature over the greater intervals to be weakened in proportion to that increase.

In the Temple at Palmyra, and in a peribolus at Djerash, two columns are joined together by their shafts; these are, perhaps, the only ancient examples now in existence of that practice. But they are sufficient to show that the clustered columns, which afterwards became such an important feature in buildings, were not unknown to the Romans; and may have been often executed by them, though the edifices thus ornamented may have been destroyed.

Orders superimposed on each other.

The great examples which the colonnades of the Roman Temples and Fora would have exhibited, of Orders superimposed on each other, are so completely ruined, that we are compelled to draw the few notions we can obtain respecting the rules of their construction from the writings of Vitruvius, and from the columns on the exterior of the Theatre of Marcellus and of the Amphitheatre of Vespasian.

According to Vitruvius, (chap. i. book v.) the following rules should be observed. The lower Order of columns should be higher than the Order next above by one-fourth; and the height of the second Order, if there are more than two, should exceed that of the third in the same ratio; by which the height of the third Order will only be equal to $\frac{9}{16}$ of the lowest; the height of the podium, or continued pedestal, which, in each Order, supports the columns, should also diminish upward in the same proportion. But there would be this inconvenience attending an adherence to these rules, *viz.* that the smallness of the diameters of the upper columns, caused by the diminished length of shaft, will render the intercolumniations of the upper Orders too great; for if the intercolumniation of the lowest Order is equal to three diameters, that of the second Order will be $4\frac{1}{4}$ diameters, and that of the third will be $6\frac{1}{9}$ diameters, contrary to the precepts of Vitruvius himself with respect to the intercolumniations.

Such an inconvenience could not have escaped the notice of an Architect who had actually designed an edifice in which two or more Orders were placed one on another; and accordingly, in the Theatre of Marcellus, and in the Colosseum, we find that the columns in the upper Orders have nearly the same height and diameter as those of the lower Order; and, consequently, the intercolumniations in all the Orders remain nearly the same.

In these buildings we remark, that the strongest Order is placed below, and the others increase in delicacy upward; a method of construction which is perfectly justified by the consideration that the strength of bodies should be proportional to the weight they have to support; and that those which have the least weight to support should be the most ornamented, provided their height above the eye is not so great as to prevent the ornaments from being seen.

The first principles of stability teach us that the axes of the upper and lower Orders of columns should be vertically coincident; yet this rule was violated in the interior of the Pantheon, where the pilasters of the upper Order stood over the intervals of those below; and in the portico of the Temple of the Sun, at Palmyra, where two columns stand over the aperture of a doorway. Many similar improprieties in the practice of the Ancients are mentioned by Serlio.

Greek sculpture superior to the Roman.

The Greeks and Romans had a great propensity to embellish their Architectural works with sculpture and painting; and the edifices of the Romans are particularly distinguished by an unsparing application of the chisel: every part susceptible of ornament being often entirely covered with representations of foliage, animals, or historical subjects. But the embellishments of the Grecian, though less profusely bestowed than those of the Roman buildings, almost invariably exhibit a superiority of taste in the design, and of skill in the execution; and it is in the sculpture of the later works of the Romans that the decline of Art is particularly observable.

Sculptured ornaments on Roman columns,

In the Roman examples, the shafts of the columns, though sometimes plain, are in general fluted, and some are even covered with sculptured foliage; in the first case they are usually formed of a different material from the bases and capitals, in order to produce a variety which may compensate for the want of other ornament. The shafts of the columns of Trajan and of Antonine are covered with figures in the directions of spiral lines round them, from bottom to top. Besides the constant ornaments of the capitals of columns, we also, occasionally, find the mouldings of the bases, and even the faces of the plinths, ornamented with guilloches, or with foliage, in single leaves, in bundles, in scrolls, or in festoons. In the Temple of Augustus, at Mylassa, the bases of the columns are ornamented above the plinths with foliage, which gives to the shaft the appearance of standing on the root of the plant, like the columns in some of the Egyptian buildings. Similar, but richer foliage, is cut above the mouldings of the bases of columns in the Baths at Nismes, and in the Baptisterium of Constantine.

on the frize,

The frizes of the Roman entablatures are distinguished by some of the best specimens of ornamental sculpture. In the Temples of Vesta, at Tivoli, and of Jupiter Tonans, at Rome, this member is adorned with ox-heads, having in the intervals festoons of flowers, or axes and vases, which are evidently intended to represent the accompaniments of a sacrifice; and in the Triumphal Arch of Titus, the same are expressed in a more elaborate manner by the entire figures of the animal, and of the persons concerned in that rite. In the Temple of Antoninus and Faustina, at Rome, and of Æsculapius, at Spalatro, are representations of griffins and vases; in the entablature of Nero are large scrolls of the richest foliage, the execution of which is equal to that of the Grecian sculpture in its best time; and at Palmyra and Balbec, the frizes are ornamented with Eagles, Cupids, and other figures, having festoons of flowers between them. It must be added that sometimes the frize is filled with inscriptions, and, in a few cases, these are contained in a tablet which occupies the height of both frize and architrave.

on the soffits of entablatures,

In the soffit of the architrave between every two columns is generally a rectangular sunk panel, either plain, or having the interior occupied by fretwork, and sometimes surrounded by a guilloche, as in the Temple of Antoninus and Faustina. In the ceiling, between the entablature of a peristyle and that of the wall of a building, are usually square panels formed in two or more depths, so that the sides have the appearance of inverted steps; these sides are usually sculptured with oves, and the panel itself is ornamented with an elegant cluster of foliage in the form of a rose. Sometimes between every two such panels is a plain square, surrounded by a rich fret in relief, as in the Temple of Mars the Avenger. In circular buildings two of the sides of each panel are in the direction of radii from the axis of the building, the other two are arcs of circles concentric with the face of the entablature, of which the Temple of Vesta, at Tivoli, affords an example. The inferior surface of the corona, in the intervals of the modillons, is commonly ornamented with square panels of small depth having a rose in the centre of each; at other times, though rarely, the soffit is plain. The inferior surface of a modillon is, generally, ornamented with a leaf resembling one of those in the Corinthian capital.

on the ceilings d buildings.

But the sculptured ornaments on the ceilings of buildings present the finest examples of elaborate workmanship. The general manner of ornamenting these parts of an edifice was by a system of panelling in circular, polygonal, or rhomboidal forms, though, occasionally, the ornaments were executed in relief. From fragments of the vaulting which once roofed the Temple of Venus at Rome, it appears that its surface was covered with square and rhomboidal panels, deeply sunk, with ornamented sides, and with a rose in the centre; in the intervals between the panels are bands of guilloches, crossing each other at right angles, and having roses at their intersections. The interior of the dome of the Pantheon is occupied by square, sunk panels in horizontal courses; and, in a similar way, the soffits of the niches and the ceilings of triumphal arches are ornamented. The ceilings of the Temples at Balbec and Palmyra are profusely decorated with panels of circular and polygonal forms, the interiors of which are filled with figures, and the margins are enriched with fretwork or elegant foliage.

Paintings the ceili and wali

The paintings on the ceilings of the Roman Baths are in general remarkable for elegance of design, and are disposed in square compartments about the centre, or along the margins of the apartments; they consist of representations of divinities and human beings; of birds, beasts, griffins, and centaurs; of medallions, and an endless variety of foliage in festoons. The sides of rooms were ornamented with perspective representations of slender shafts, like rods, supporting light entablatures, or canopies with circular or triangular pediments above: among these are representations of statues, tripods, and vases, with drapery and foliage in festoons, and in some places are views of gardens. The Baths of Titus and those at Herculaneum afford great abundance of these paintings.

CHAPTER VIII.

Practice of Roman Building.

Manne describi the Ro mouldi

The mouldings used in the Roman Architecture are mostly of the same denominations as those in the Grecian, but the profiles and elevations of the first are formed by arcs of circles, whereas the latter are portions of conic sections. See pl. ii.

The torus and astragal are both semicircles, the diameters of which are equal to the height of the moulding, and they only differ from each other in their magnitude.

The ovolo is a quadrant of a circle, the convex surface of which is outward; its semidiameter is equal to the height of the moulding, and its centre is in a horizontal plane passing through the upper extremity. This moulding generally occupies the place of the echinus in the Grecian Architecture.

The cavetto is described in the same way, being also a quadrant of a circle, but its concave surface is outward, and its centre is in a horizontal plane passing through the lower extremity.

The apophygis, if it is a quadrant of a circle, is also described in the same manner as the former mouldings, but it, generally, does not exceed an arc of 60 degrees; in which case the centre is at the vertex of an equilateral triangle formed on a line joining the two given points through which the curve is to pass; it is necessary, however, that the centre should be in a horizontal plane passing through the column in the place where the apophygis joins the shaft, otherwise the profile of the column will appear broken at that place.

The cima recta may be described by dividing the line joining the extremities of the fillets above and below in two equal parts by a line parallel to the fillets, and describing a quadrant of a circle on each half, on contrary sides of the first line; the centres for describing the quadrants will be in the second line; and this construction supposes that the projection of one fillet beyond the other is equal to the height of the curvilinear moulding.

The scotia is sometimes described by joining the extremities, *a b*, of the fillets above and below; (see pl. x. fig. 9.) and upon *a b*, as a diameter, describing a semicircle, in which case the upper surface of the lower fillet is rendered a little concave; but usually the scotia consists of portions of two circles, which may be described in the following manner. Draw the indefinite lines *b m* and *a n* parallel to the axis of the column; upon *a b* describe a semicircle as before, and draw *b c*, making the angle $m\,b\,c = 60$ degrees, to cut the semicircle in *c*; lastly, draw *c d*, making the angle $b\,c\,d = 60$ degrees, and meeting *a n*, *m b*, in *e* and *d*; *d* will be the centre of the arc *b c*, and *e* the centre of the arc *a c*; and these arcs form the scotia required. The curves will not appear broken at *c*, because a line at *c*, perpendicular to *d c*, will be a tangent to both.

The Ionic volute is an ornament which is required to be drawn with considerable exactness; and methods have been given for describing it, by Vignola, Sir William Chambers, and Goldman, on the supposition that the spirals are formed by the union of several circular arcs. The rules delivered by Goldman seem to afford the most elegant form, and therefore we may confine ourselves to them. See pl. x. figs. 7 and 8.

He supposes the whole height A B of the volute to be divided in C, in the ratio of 9 to 7, then the point C becomes the centre of the volute; about this point a circle, *a b*, is described with a radius equal to $\frac{1}{18}$ of A B, and this forms the eye of the volute. On the diameter *a b*, he takes from the centre C, the distances C *m*, C *n*, each equal to one-fourth of *a b*, and divides each of these into three equal parts in the points *o*, *p*, *q*, *r*; on *m n*, *o r*, and *p q*, he forms squares, and produces their sides indefinitely, as in figure 7; then *m*, *s*, *t*, *n*, *o*, *v*, &c. become the centres for describing the several quadrants of the volute.

Having determined the breadth A D of the baltheus or listel at the top of the volute, he makes A *z* equal to half the side of the square *s n*, and joins *z* C; through D, he draws D *d* parallel to A *z*, and divides it into three equal parts; he then makes C m', C o', C p', respectively equal to D *d*, D *e*, D *f*, and sets equal spaces below C, and forms squares on $m'\,n'$, $o'\,r'$, $p'\,q'$; the angular points of these squares become the centres for describing the interior quadrants of the volute.

When the volutes are formed obliquely to the face of the abacus, as are those of the Temple of Concord, of the angular columns in the Temple of Fortuna Virilis, and those in the capitals of the Composite Order, the spirals, when represented on paper, become portions of ellipses; the vertical axes of the ellipses, that is, those which coincide in direction with A B remain of the same length as when the planes of the volutes are parallel to the face of the abacus, but the horizontal axes are all diminished in the ratio of radius to the cosine of the angle of obliquity; the several horizontal axes being thus determined, the spirals may be traced by the usual rules for describing ellipses.

The ornaments in the Corinthian and Composite capitals must be traced by hand; and it will be only necessary to observe that the leaves of the former resemble those of the laurel, or of the olive; those of the latter, of the acanthus, or of parsley.

Optical modification of a profile.

Vitruvius observes, that the magnitudes of objects should be changed according to their situation with respect to the eye; and it can be conceived that this must be true, when some of the projecting members might conceal others which, from their essential character, or their embellishments, ought to be visible. In such a case we immediately conclude that the projection should be lessened, or the parts above and below should be increased in height beyond the quantities assigned by the general rules; and that the faces which are usually vertical should be made with their upper extremities inclining forward or backward, in order to cause them to be seen to advantage. For the same reason the superior surfaces of mouldings which have considerable projection, instead of being horizontal, should be in planes inclining upward towards the face of the building, or in the form of a curve concave outwards; as is often the case with the fillet between the architrave and frize. Such deviations from the general rules are observed in the great works of the Romans; but it is necessary to understand, as has been observed by Newton, the translator of Vitruvius, that they should only take place when the object is viewed from a situation to which the spectator is unaccustomed; for, in most ordinary situations, however the eye may be elevated above or depressed below the object, the mind has the power of rectifying the perceptions produced by the images actually transmitted to the eye; and the objects appear, not as we see them, but as we have found them to be by previous experience.

Rules for the foundations.

In the Vth chapter of his Ist Book, Vitruvius, describing the building of walls, says, the ground is to be dug down to, and even into the solid earth; the foundation walls to be thicker than those which are built above ground, and executed in the firmest manner. And in chap. iii. book iii. he says, the stereobata, or the walls above ground, on which the columns stand, are to be thicker by half than the diameters of the columns themselves. He adds, if the ground is soft and marshy, it must be excavated, and piles of scorched wood driven in very close together, and the intervals filled with charcoal. No rule, however, is given by Vitruvius for the depth of the foundations below the ground, but the general practice of the Ancients seems to have been to make it equal to one-sixth of the whole edifice. He recommends to sink the wells, cisterns, and drains, previously to laying the foundations, as well to ascertain the nature of the ground, as to supply the wants of the inhabitants.

Dimensions of walls.

Besides the general rule that the thickness of a wall should be proportional to the magnitude of the edifice, Vitruvius directs, in the XIth chapter of his VIth Book, that buttresses should be erected in front of the foundation-walls, in order to resist, as he says, the expansion of the included earth when swollen by rain; and he directs that the distance between every two should be equal to the depth of the substructure below the general level of the ground. Their thickness he recommends to be the same as that of the foundation-wall; their upper extremities, probably, coincided with the surface of the wall at the level of the ground, and their lower extremities projected from the surface of the wall as much as the thickness of the wall itself. He also proposes that walls should be built as high as the level of the ground within the interior space, and disposed in triangular forms on the plan, one side of each wall coinciding with the interior face of the building itself, the better to enable the side of the building to resist the outward pressure of the included earth.

Methods of building walls.

The ancient Etruscan or Latin walls were constructed of large, square masses of stone without cement; but during the existence of the Republic, this method of building seems to have given way to the formation of what was called the *incertum opus*, which consisted of small stones mixed with mortar; and specimens of it are still to be seen in the Temples of Vesta, at Tivoli, of Fortune, at Præneste, and in many other edifices; but Mr. Ramage observes, that this species of work must not be confounded with that formed of large stones in the shape of irregular polygons, as may be seen in the walls at Cora, Præneste, and other ancient cities of Latium, which is of an older date. The Roman *emplecton* was employed, probably, during the same period; it was similar to that of the same name, which was in use among the Greeks; but seems to have been executed less carefully, the rubble stones being thrown promiscuously with mortar between the faces of the wall; and Vitruvius justly gives the preference to the method of the Greeks. To these succeeded the *reticulatum opus*, which must have been fashionable in the time of Vitruvius; it was composed of stones or bricks made in the form of rectangular prisms, and disposed with their diagonals in vertical and horizontal positions, so that the face of the wall had the appearance of network. When this was used, bricks or rectangular stones in horizontal courses were employed at the quoins, or angles of the walls, in order to give it stability. Vitruvius seems to consider this as beautiful; but certainly from the oblique pressures which the bricks must have exerted against each other, in consequence of the weight of the mass above them, it must have been very liable to give way, and perhaps it could hardly have stood a moment, but for the cohesive power of the mortar. This species of wall is said by Mr Ramage to have continued in fashion till the time of Caracalla, and examples of it are to be seen in the Garden of Sallust, near the Quirinal Hill, and in the Palace of Mecænas, where it is mixed promiscuously with brickwork.

In great works, like the towers and walls of towns, we find that the general method of construction was to dispose the rubble stones as regularly as the nature of the material would admit, in horizontal courses; and at distances of three or four feet above each other were placed horizontal courses of broad flat stones to bind the whole together. Remains of this kind of masonry are very abundant in England, and examples of it may be seen in the walls of Richborough castle, in Kent, and of Silchester, in Berkshire; in these places the rubble is disposed in alternate courses of rough rag-stone, large flat bricks, and layers of solid mortar; the whole has been mixed with liquid mortar, which united the materials in a hard and strongly coherent mass.

To connect the parts of a wall together, or perhaps to lighten the pressure on particular parts of the foundation, it seems to have been customary to form, in the thickness of the walls, one or more rows of arches, like those in the walls of the Pantheon, consisting of two or more concentric courses of voussoirs; and within the intrados of the arch are horizontal courses of masonry, as in the rest of the wall.

Kinds of stone employed in Roman buildings.

Mr. Ramage observes, that the stone employed in the buildings of ancient Rome is of five different kinds. The first, called by Vitruvius *Lapis ruber*, and by the Moderns *Tuffa*, is a volcanic production, and is employed in the foundations and walls of buildings; the Temple of Fortuna Virilis and the Aqueduct of Claudian are built of this stone; which, in the latter building, is cut in large masses, that it may better resist the action of the air, by which it is liable to be decomposed. The second, called *Lapis Albanus*, or *Peperino*, is also volcanic; the more ancient Italian buildings, as the *Cloaca Maxima*, and part of the Tullian walls under the Quirinal Hill, are built of this stone, which is more solid and less subject to decomposition by the air than Tuffa; it is also capable of resisting the action of fire. The third, called *Lapis Tiburtinus*, or *Travertino*, is a calcareous concretion which was brought from the neighbourhood of Tibur: it has the quality of hardening by exposure to the air, but is decomposed by fire; when employed in building it is cut in large quadrangular masses, which are put together without cement. The Temples at Pæstum, the Colosseum, and the Sepulchre of Cecilia Metella, are built of this stone. *Silex* was frequently employed in paving streets, and filling up the interior of walls; and Pumice-stone, obtained from Asia, Spain, and Marseilles, so light as to float in water, was, on that account, used in the formation of vaults: those of the Colosseum, and the dome of the Pantheon, are partly constructed of this last material. The Silex was a basaltic, and the Pumice-stone a vesicular lava, but neither of them are of the same species as the stones which now go by those names.

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Brickwork continued in use till the fall of the Empire, and, at first, it was nearly equal in strength to stonework; but, in the later times, it had not its former solidity, on account of the greater quantity of mortar employed. Vitruvius says, that the Greeks used square bricks equal to 5 palms, or 15 inches in length and breadth, in their public works, and others equal to 4 palms, or 12 inches in length and breadth, for their private dwellings; they also used half-bricks, and placed them with the whole bricks in alternate courses. The Roman bricks, or tiles, were of finer quality than those made at present, and were either square or parallelogramic; the former were sometimes 18 inches long and broad, and the latter 12 inches long and 6 inches broad; and in the times of Augustus and Tiberius, the bricks were occasionally made of a triangular form, as may be seen in part of the remaining walls of Rome. Vitruvius does not specify any thickness for bricks, but it was in general small, in some cases not greater than one inch. It may be added that this author describes only unburned bricks, and he recommends that they should not be employed till after they had been made at least two years.

It seems to have been the opinion of the ancient Romans that an edifice of brick was more durable than one of stone; for Milizia says, they estimated the value of a stone-building every year less than in the preceding year, by one-eightieth part of the whole, supposing that it would last only eighty years, whereas they estimated the value of a brick-building always at the same sum, as if it were indestructible. It is probable that the stone here supposed to have been employed was of a very inferior character.

The Romans used a species of mortar now called *Pozzolana*, from Pozzuoli, anciently Puteoli, the name of the place wherein it was first made; it had the valuable quality of hardening in water, so as to form with the stones or bricks a solid mass uniformly consistent. The harbour at Antium and the mole at Pozzuoli, the latter of which was probably erected near the Augustan Age, afford the best proofs of the durability of this material.

It seems unnecessary to dwell longer upon the detail of the practice of the Ancients in the mechanical construction of their edifices; because, though it was in general good, and it even forms the basis of the practice of Architects in the present day; yet the progress of improvement and the circumstances of climate and of manners, have necessarily brought on such changes as render an adherence to their rules impossible.

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The Grecian artists produced simplicity and unity in their most magnificent designs by forming a system of unbroken horizontal lines in the lower and upper parts of the buildings; these occur in the steps and in the divisions of the entablature, and give to those members the appearance of bands uniting the extremities of the columns in one entire system, while they indicate at a glance the whole length and breadth of the building. The sides of the columns present also a system of lines, nearly vertical, which serve to mark its height. The system is completed by adding a low pediment which forms a cover to the whole just sufficiently raised in the middle to throw off the gentle showers of rain which fall in a climate in which the atmosphere is seldom troubled by violent storms, without interrupting the general effect of the vertical and horizontal lines of the building.

Abundant in well-executed sculpture as are the members of the Grecian buildings, the variety of form produced by the chisel is not suffered to interfere with the outline, being sunk within the general face of the building. The mouldings only of the capitals and entablatures break the rectilinear character of the edifice, and diversify a style otherwise too monotonous, by the graceful curves which they exhibit in profile. Large masses of shadow, projected by the peristyle and its entablature, fall upon the walls of the building, and powerfully contrast with the light reflected from the curved surfaces of the columns themselves which surround the building, and produce a long succession of alternate lights and shades which change every moment with the position of the Sun and the eye of the observer.

Rome, in the zenith of her prosperity, copied, with some modifications, the Architecture of Greece; but though her works might sometimes surpass their originals in magnificence, they almost always remained inferior to them in purity of taste. Vitruvius, indeed, professes to have formed his rules from the buildings and writings of the best Grecian artists, yet he laboured under the disadvantage of not having seen the former; and perhaps the latter were the works of men who lived near his own times, when a considerable change had taken place in the style of the Architecture, even of Greece herself; and, lastly, from the loss of the drawings, which originally accompanied his manuscript, we remain in doubt of the precise meaning, and the effect of many of the rules he has delivered.

In the best times of the Roman Architecture, the Temples of Italy might be little inferior, in merit, to those of Greece; a similarity of form was adhered to, and perhaps the modification of the proportions of the columns and their entablatures was but of small moment; it might even happen that this was rather to the advantage of the Roman Architecture by rendering those members of the edifices lighter than the corresponding ones in the Greek examples. The almost general adoption of the Corinthian Order in Italy was also the means of producing a degree of embellishment superior to that of the Doric Order which had formerly prevailed on the opposite shores; but a great difference took place in the exterior forms of buildings by the construction of brick-domes, high pediments, and the piling of one Order upon another. Of the domes it may be said that they afford a convincing proof of high mechanical skill; and that they constitute a feature which is capable of exciting sublime emotions, by the view of an immense mass of solid materials suspended in the air; and which, by the application made of it in later times, has given to buildings a degree of magnificence superior perhaps to that of any production of the ancient schools. We have shown how much the inclination of the sides of the pediment of the Pantheon exceeded those of the Grecian Temples; and though the Romans did not always give so great an inclination as we find in that example, yet such was the general case. These high-raised roofs are far from producing so pleasing an effect as the others, either because they interfere too much with the system of horizontal and vertical lines in the building, or because they afford indications of less skill in resisting the lateral pressure of the rafters, which in low roofs is very considerable; though in a climate more rude than that of Greece, the utility of the higher pediments is undoubted.

The supraposition of Orders is not without a reasonable excuse, if it have not, in some cases, the plea of necessity. In Theatres, and such buildings where great height was required for the exterior wall, it would have been impossible to make one Order of columns extend from bottom to top; and an obvious measure was to consider the building as divided into several stories, and to mark each story by a particular Order, the entablature of which might correspond with the floor in the interior. Single Orders are employed in the peristyles of the cavædia; but there the floor is supported by *parastatæ*, or posts attached to the shafts of the columns, a mode which can hardly be considered as exhibiting either skill or science: the great column is evidently unfit for its purpose, and two Orders in such situations would have been more natural than one thus broken.

We have had occasion to mention the magnificent works of Augustus, Vespasian, Trajan, and Hadrian; and we may also add, from Gibbon, that it was not only the Sovereigns of Rome by whom the Empire was adorned; this honour was shared with them by the Governors of Provinces, and even by private individuals. Among the works of the latter he enumerates those executed by the munificence of Herodes Atticus, a citizen of Athens, from which a notion may be formed of the encouragement given to Architecture by the wealthy subjects of the Empire. But when the extravagant follies of the Emperors had diverted the treasures of the State from their legitimate uses; *viz.* the defence and embellishment of their dominions; and when the insecurity of property prevented even individuals from displaying their taste in the erection of public or private edifices, then the cessation of the demand for the talents of the artists necessarily led to a neglect of the study of the principles which are the foundation of a pure taste in the Arts of design; so that when, at the command of a Prince more enlightened than many of his predecessors, a new edifice was to be constructed, nothing remained in the power of the artist, if he did not copy mechanically the whole of some building already in existence, but to introduce in his design the different members employed in some similar work. This seems to have been often done without regard to their connection with each other; and from ignorance of their just proportions, they have been altered and distorted according to the fancy of the artist; while the surface of the work has been covered with a profusion of ornament equally destitute of propriety and elegance.

The patronage of Dioclesian and Constantine, it has been observed, produced a gleam of taste which shone with faint lustre for a short time; but from the death of the latter may be dated the period of a complete corruption of the Art. Symptoms of decline are exhibited, principally, in the Triumphal Arches of Severus, Gallienus, and Constantine; in the edifices of Palmyra and Balbec; and in the Palace of Dioclesian at Spalatro. In all these we find the members overloaded with ornaments badly sculptured; in some we find columns have been taken from other edifices and cut to the required length, when too long, without making a corresponding diminution in the bulk of the shaft; or, when too short, they have been mounted on pedestals. The entablatures are often broken, and form projections over the capitals of the columns attached to the walls; thus destroying the unity of the horizontal band, and the fine effect arising from the long lines of shadow above the columns; while the pedestals interrupt and spoil the effect of the continuous basement; and the frize, instead of presenting a vertical face, is cut in a cylindrical form, and resembles a beam crushed by the weight of the cornice above. In some cases, columns with spiral flutings were capriciously employed, in direct contradiction to the first principles of stability, and exhibiting the appearance of ropes employed as props to sustain the roof of a building. Pediments are inscribed in each other; some have not the horizontal cornice; others are bounded by a curve at top; occasionally the tympanum is broken vertically into three different faces; and finally, there are some in which the inclining sides are not continued to the apex. All these circumstances are so many gross deviations from the classic styles of Greece and Rome; and like the gilded statues and colossal figures of the same period, are indications that, in Architecture and Sculpture, the minds of men were then disposed to run into the wildest excesses.

In the Arch of Hadrian, at Athens, the archivolt rises from the top of a short pilaster attached to the wall. But it is in the Palace at Spalatro that we find the earliest examples of arches springing from the tops of columns; a practice which afterwards became common in Ecclesiastical edifices, but which, applied as it is in this building, is a signal example of a corrupt taste; for whatever may be the real strength of a column, it does not appear adequate to the support of an arch and the building above it; nor is it in reality capable of resisting the thrust which every arch exerts in a lateral direction outward upon its points of support; piers alone, which may have any breadth required, appear adapted to these purposes. It may be observed that Sculpture declined before Architecture, and this is what might be expected; since though to design a building may require a greater effort of genius than to form a statue, yet it is obviously much easier to copy the proportions of an edifice than those of a human figure; and, in fact, some of the most magnificent edifices of Rome were erected in an Age when Sculpture had ceased to exist as a Fine Art. We may remark here that the corrupt style of the later Ages of Roman Architecture, and even the forms and proportions of that since denominated Gothic, are visible in many of the representations of buildings depicted on the walls of Herculaneum and Pompeii.

CHAPTER IX.

Ecclesiastical Edifices of the Western and Eastern Empires.

Probabiliy that Christian Churches existed before the time of Constantine.

Before Christianity became the established Religion of the Roman Empire, the Christians seem to have had regular Churches for the performance of divine worship; for Eusebius relates that in the beginning of the reign of Dioclesian, they both repaired the older edifices, and built new ones of considerable magnitude. The anger of Dioclesian, also, is said, by Lactantius, to have been excited by a new Church which had been built at Nicomedia; and the edict issued by Constantine for repairing as well as rebuilding the Churches is a proof that such must have existed before his time.

The heat Basilicæ used as Churches in the We

It is reasonable to believe that in the infancy of the Religion, and subsequently, in times of Persecution, those who had embraced its tenets, and had thus rendered themselves obnoxious to the Civil power, would hold their assemblies in private houses, and even, as they are said to have done, in the public catacombs, in order to elude the vigilance of their persecutors. But this secrecy was not likely to be continued, by a people zealous in the cause of their Master, longer than they were compelled to it by necessity; and as soon as their increasing numbers required more space, or the storm of persecution was abated, it might be expected that the Faithful would endeavour to obtain possession of public buildings for the purposes of Religion. That opinion, therefore, is probably not correct, which has been asserted; *viz.* that the Christians had no public Churches till the time of Constantine. But the intervals of the Persecutions being short, it would perhaps not often happen that buildings could be purposely erected to serve as Churches; and the people would be induced to avail themselves of a species of building already existing, and which could easily be adapted to their circumstances. This was the Basilica, or Court erected for the administration of justice, of which we have already spoken generally, in our *Miscellaneous Division, ad v.* We shall here more particularly describe their construction. Even after Constantine had delivered the Church from her enemies, and a public profession of Christianity could be made with safety, the Heathen Temples were rejected, and the Basilicæ were preferred, probably because they had not served for any superstitious purposes, and were more convenient for the celebration of Christian worship. Afterwards the Churches purposely erected, at least in the Western Empire, were designed in accordance with the plan of such buildings; and hence the first Churches were called Basilicæ, and that name has been since retained, though the forms of the more recent Churches often differ entirely from those of the buildings from which they are derived.

Convenience of the Basilicæ for Religious ervice.

The celebration of Heathen worship was accompanied by the slaughter of animals, which was most conveniently performed in the open air; where, or under the colonnade surrounding the Temple, the bulk of the worshippers remained; therefore there was no necessity for great capacity in the interior of the Temples. But the Christian worship consisted in public prayer, and catechetical exercises, accompanied by the delivery of lectures; and these, being best performed under cover, required Religious edifices large enough to contain a numerous congregation; such were the Basilicæ, being spacious buildings roofed over and abundantly lighted by windows.

General rm of the Basilicæ.

The great Basilicæ of the Heathens were of a rectangular form, and divided into three or more parts by rows of columns parallel to the length of the building; another colonnade, at each extremity, crossed the former at right angles, and in the middle of one of the end walls was a hemicylindrical recess in which was situated the tribune of the Judge; the colonnades of the aisles being discontinued when they arrived near the tribune, there was formed a transverse division at that end of the building; and, thus, the interior division assumed the figure of a cross. The recess, formerly occupied by the tribune, was found a convenient place for the altar; which continued to occupy that station till the desire of giving to the plan of the Church, on the exterior, the form of a cross, induced the artists to add to the original rectangle, of which the plan consisted, another crossing it at right angles at or near the middle of its length; then the altar was placed in the intersection of the two, which, from this time, became the most important place in the Church; and, as a mark of distinction, was subsequently covered by a dome or cupola, rising above the general roof of the building.

The circular recess at one extremity of the Basilica gave the building something like the appearance of a ship; and from this circumstance, probably, the body of the Church or Basilica was called the *nave*, a term which was afterwards confined to the central division between the parallel rows of columns. The lateral divisions were called *aisles*, and the two arms of the transverse rectangle, which crossed the principal building at right angles, *transepts*. In the Churches of Italy, and all those which were copied from them, this transverse building was placed at or near one extremity of the main body of the edifice; but in Asia, Constantinople, and Greece the forms of the Churches, at least of those which were erected in, or subsequently to the time of Justinian, were rather different; the plan of most of them consists of two rectangular parallelograms intersecting each other perpendicularly in the middle, in such a way as to make the four arms of equal length; and the centre, like that in the Italian Churches, is covered by a dome. This plan bears the name of a *Greek cross*, to distinguish it from that of the Western Churches, which is called a *Latin cross*.

The ancient Basilicæ frequently had upper galleries between the columns and the interior of the walls; and when these buildings were dedicated to the service of Religion, or Churches were erected according to the plan of those buildings, the upper galleries were frequently appropriated to the female part of the congregation, which in the ancient Christian Church was separated from the male part: and the ascent to them was by steps in the thickness of the walls, so that the women could arrive at their places without being seen by those persons who were in the lower part of the Church.

Constantine promotes the building of Churches at Rome.

The Religion of Christ becoming, in the reign of Constantine, the Religion of the Empire, that Prince directed a portion of his own wealth and that of the State, to the noble purpose of erecting, for its service, edifices which might be worthy of the Roman name. Seven Churches, built or consecrated within or near the city of Rome, are described as the fruits of his zeal; and though not one of them remains in its original state, it is incumbent on us to mention some of them, because they were, in their time, objects of great importance, and were also the first works of magnitude which were appropriated to the celebration of Christian worship.

The Basilica of St. John de Lateran.

The first of these is the Basilica of St. John de Lateran, which was originally part of the Palace of Plautius Lateranus, and subsequently of the Emperors of Rome. Constantine, to whom it belonged, caused it to be dedicated to the Saviour, to St. John, and St. Peter. Being now entirely modernized, it is impossible to give an accurate description of it; but, according to Rasponi, it was of a rectangular figure, except at the Eastern extremity, where was a semicircular recess; the body of the Church was divided longitudinally, by four parallel rows of columns, into five parts, forming a centre, or grand nave, and two aisles on each side.

The Baptisterium of Constantine.

Contiguous to this, and forming part of the ancient Palace, is a building serving for a Baptistery, and supposed also to have been built by Constantine. The plan is a regular octagon, and there is a descent by four steps to the bottom of what was originally the basin, a superb vessel of basalt for the immersion of the converts. Eight columns of porphyry surround the central part in the interior of the edifice, and above the entablature are eight smaller columns of white marble; these bear a heavy entablature, above which, at the angles, are pilasters supporting the dome of the edifice; and a remarkable circumstance is, that between these Orders there is no ceiling, either over the centre or over the gallery between the columns and the wall. The materials of which this edifice is composed seem to have been taken from other buildings, and the borrowed columns appear to have been put up in haste, without even reducing them to one size of shaft.

The Basilica of St. Peter,

The Basilica of St. Peter was built on the North side of the Circus of Nero, perhaps with the materials of the Circus itself, and was consecrated by Constantine in the year of Christ 324. This edifice is supposed to have had the figure of a cross on the plan, and was, probably, the first of the kind. The body of the Basilica is said to have been 200 feet long from East to West, and 154 feet wide, according to the measurements of the Abbé Uggeri; and to have been divided into five naves by four parallel rows of columns. The transept, if it may be so called, was at the Eastern extremity, and equal in length to 208 feet from North to South; in the middle of the Eastern face was the semicircular *chalcidia* or *apsis*, which was about 43 feet in diameter;

and at the Western extremity, in front of the doorway, was a grand rectangular peristyle. The whole building is described as exceeding in magnitude and splendour any Temple before seen, having in it an hundred marble columns; but it is allowed to have had small pretensions to architectonic merit. Being destroyed by the Saracens in 846, it was restored by Probus, probably on the traces of the more ancient building. It was again demolished by Pope Nicholas V., and the present grand Cathedral of St. Peter was subsequently built on the same spot. For a plan of this Basilica see pl. xiv.

of St. Laurentius,

The Basilica also of St. Laurentius, at Rome, was one of the seven Churches built by Constantine. It is now of a rectangular form, and without the chalcidia or semicircular tribune; therefore, probably, the plan has been changed since the original construction. Its interior length is 296 feet, and breadth 70 feet. In front is a pronaos with six Ionic columns between the antæ. The nave beyond is divided into three parts longitudinally by two rows of Ionic columns, and within the centre division, or grand nave, are two *ambones* or pulpits, one on each side, elevated above the level of the pavement with steps to ascend to them; at the further extremity of the grand nave is the Presbytery, or division appropriated to the officiating Priests, which is enclosed by a rail. Beyond the nave is the Choir or Sanctuary, of a rectangular form, elevated above the general pavement of the Church, and having an aisle on each side on a lower level. This elevation seems to have been made at a time posterior to the building of the Church in order to obtain a space below for a Crypt or lower Chapel. On each side of the Choir are five fluted Corinthian columns, the bases of which are on the pavement of the aisles. The capitals of these are of different kinds, and they carry an entablature ornamented with sculpture, good and bad; above these is another Order of Corinthian columns of smaller size, with spiral flutings, and over them are arches and a wall pierced by windows. Between the extremity of the Choir and the Eastern end of the Church is a Chapel, the pavement of which is on a lower level than that of the nave; and it is supposed by some that this was originally the vestibule of the building.

of St. Paul,

The Basilica also of St. Paul, on the banks of the Tiber, was built originally by Constantine; it was subsequently enlarged, but according to the same plan, by the Emperors Valentinian, Theodosius, and Arcadius. This building also, which still exists, has the figure of the cross, and the transept is placed at the Eastern extremity, but its length only exceeds the breadth of the body of the Church by a few feet. The length and breadth of the latter are 296 feet and 215 feet respectively, and it is divided into five aisles longitudinally, by four rows of columns of the Corinthian Order; twenty-four of the forty columns in the two interior rows are supposed to have been taken from the Mausoleum of Hadrian, and the rest are of the time of Theodosius and Honorius. The entrance from the central nave to the transept is covered by a grand arch, springing from two columns of the Ionic Order with Attic bases. The transept, which is 79½ feet wide from West to East, is divided into two equal parts by a wall and columns in a Northern and Southern direction; in the centre of this wall is an arched entrance opposite to the former, and, as in that, the arch is supported on two columns. At the Eastern extremity is the tribune or apsis, in the form of a segment of a circle on the plan, and lined with mosaic work. All the columns of the nave support arches; above those on each side of the central division are high walls, adorned with Paintings which are divided into two rows; and at the top of this wall, on each side, is a tier of arched windows filled with plates of Parian marble and pierced with round holes in several rows. Almost every column is formed of a single block; the shafts are fluted and the channels are cabled, or filled as far up as one-third of their height; but the flutes and capitals are badly cut, and the former are not even straight.

of St. Agn

The Church of St. Agnes, without the walls, is another of the works of Constantine; its plan is rectangular, 99 feet long and 53 feet broad, and it has no transept, but there is a semicircular recess at the Eastern end. The Church is divided into a grand nave and two aisles by two rows of columns, each consisting of two Orders one above the other; and over the aisles is a gallery on each side, as was usual in the Heathen Basilicæ. The walls of the recess are covered by plates of white marble, ornamented alternately with little bands of porphyry in the form of small pilasters; of these two are curious in the two angles of the apsis, with capitals of the Corinthian Order; they have very little relief, and are executed in the bad style of the Lower Empire; one of them has also an Attic base as badly executed as the capitals.

Dr. Milner has given a copy of a mosaic picture executed by order of Pope Honorius, about A. D. 621, representing this Church in its original state; from which it appears that the walls of the nave were carried up higher than the four exterior walls of the Church, and were pierced by semicircular-headed windows along the sides and front. The Church seems to have been covered with tiles; the roof of the nave terminated in a ridge extending longitudinally over the middle of the building, and in the gavel, or triangular front at the Western end, was a circular window. At the Western extremity of the body of the building was the *narthex*, or porch for Penitents; the entrance to which from the street was closed merely by a curtain.

of St. Stephen

We may conclude this account of the ancient Roman Churches with a description of the circular building dedicated to St. Stephen, which bears marks of having been executed in the latest period of the Roman Empire; probably on the ruins and with the materials of a Temple dedicated to Claudius. The exterior wall is 211 feet diameter; within this is another the diameter of which is 80 feet, in the interior circumference of which are eight pilasters at unequal distances from each other; and between these are alternately four and five columns half sunk in the wall; some of the columns are larger than the others, and have Corinthian capitals; the capitals of the others are of the Ionic Order. The shafts of some are plain, of others fluted, and all of them support a small cornice which is broken so as to project over each column. Above these columns is a cylindrical wall with arcades. Within this colonnade is another, 77 feet in diameter, which consists of isolated columns all of the Ionic Order, supporting an architrave, and having bases of all sizes and kinds. At the extremities of a diameter of this colonnade are two piers ornamented with Corinthian pilasters, the faces of which are towards the centre; and in the interval between them are two large Corinthian columns, which, with the pilasters, support three arches in the direction of a diameter of the building; on them rests the timberwork of the roof. The Grand Altar is in the centre, and there are other altars in the circumference of the exterior colonnade.

Ecclesiastical edifices must have been erected in Syria and Greece in the very infancy of Christianity, and before any were erected in Rome; those Countries being so much nearer to the place whence the Religion emanated. Of those edifices the erection of which was anterior to the time of Constantine not a trace now remains by which we can judge of their forms; but Mr. Whittington supposes, in his *Ecclesiastical Antiquities of France*, that they were generally of an oblong figure, and that near each of them may have been a lodging for the officiating Priest.

Works of Constantine at Byzantium.

When Constantine removed the seat of Empire to the city which he called by his name, he adorned his new residence with so many stately edifices that it became nearly equal in magnificence to the ancient Capital itself. Besides a Cathedral dedicated to Sancta Sophia, or Holy Wisdom, and a Church to the Apostles, he built a Forum of an elliptical form, surrounded by colonnades and statues, having its opposite entrances formed by Triumphal Arches, and a lofty column in its centre; a Circus or Hippodrome, about 400 paces in length and 100 in breadth, having the space between the metæ or goals filled with statues and obelisks. And, within a century after its foundation, Constantinople is said to have contained a School of Learning, a Circus, two Theatres, eight public and one hundred and fifty-three private Baths, fifty-two Porticos, fourteen Churches, and as many Palaces.

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The pious Helena, mother of Constantine, about the same time, caused several edifices for Christian worship to be executed in the East; the most celebrated of which seems to have been the Church of the Holy Sepulchre at Jerusalem. According to M. Deshayes, Helena only built that part which covers the sepulchre, and succeeding Princes augmented it so as to include Mount Calvary. Its form is very irregular, being subject to the inequalities of the ground, but it nearly resembles a cross; its length is 120 paces, and breadth 70 paces. M. Chateaubriand shows that the whole building consists properly of three Churches, *viz.* that of the Holy Sepulchre, that of Calvary, and that of the Invention of the Cross. The first is of a circular form, and constitutes the grand nave of the whole edifice; its interior circumference is ornamented with two tiers of marble columns, sixteen in each, supporting two tiers of arches. The columns of the upper tier are smaller than those of the lower, and form the front of a circular gallery; and a row of niches is formed in the interior circumference of the wall, corresponding to the apertures of the lower arcade. This part of the building is, or rather was, covered by a timber-dome in the form of a frustum of a cone, 30 feet diameter, with an aperture at the top like that of the Pantheon at Rome. The Sepulchre is under the middle of the dome, and consists of a rectangular excavation in the rock, the entrance to which is by a low aperture; the interior is nearly square on the plan, 5 feet 10 inches long each way, and about 8 feet high. The Choir of this Church is on the Eastern side of the tomb, and is divided into two parts; in the first are the stalls for the Priests, beyond this is the Sanctuary which is raised a little above the level of the former part, and on each side of it is an aisle, in which several small Chapels or Oratories have been formed. In the right aisle are two entrances, one of which leads by a vaulted staircase to the upper part of the rock of Calvary, where is formed the Church of that name; and the other, by a descending staircase, to the Church of the Invention of the Cross; and both these Churches are covered by small domes. The Architecture is of the Age of Constantine, and it is probable that it has not been essentially changed since the time of its first erection. The columns, which are of the Corinthian Order, are mostly heavy and ill-proportioned. The Church has no peristyle, and perhaps it never had any exterior ornament. M. Chateaubriand relates that since his return from Syria, the Church of the Holy Sepulchre, perhaps he means its timber-dome, has been destroyed by fire.

Church of the Nativity

The Church of the Nativity, at Bethlehem, which seems to have been executed in this Age, is of a rectangular form; the body is divided into three parts by two rows of Corinthian columns, and in the walls of the central division, above the columns, are semicircular-headed windows. But what is remarkable in this Church is, that the walls between the windows are covered with mosaics, representing buildings in which are twisted columns, and others the shafts of which are ornamented with zig-zag grooves across them, very much in the style of those employed in the Saxon or Norman Churches erected about the Xth century.

Distribution of the interior of the ancient Churches.

The façades of the primitive Greek Churches are said to have been originally turned to the East, in order that the Priest in celebrating the service might have his face turned that way; but the practice was not general, for in some cases, as in the Church at Antioch, the principal façade was towards the West; and among the Latins this last disposition was that generally adopted. The semicircular recess at one extremity of the Basilica had the name of apsis, from a Greek word which signifies an arch; and this was the place destined for the throne of the Bishop. In front of the apsis or tribunal, was the Sanctuary or Chancel, a part surrounded by a balustrade in which was the Grand Altar, and into which only the Ministers who officiated had permission to enter: this was elevated a few steps above the pavement, and, according to Eusebius, it was divided from the rest of the Church by a lattice-work of wood. The Chancel and Altar were generally situated at the Eastern extremity of the building, in order that the congregation might, in prayer, have their faces towards the Altar, when, agreeably to the custom mentioned by the early Fathers, the people turned to the East in that act of devotion. Near the Sanctuary were the *ambones* or pulpits, which were placed one on each side of the central division of the nave; these were also elevated above the general pavement, and from them the Epistle and Gospel were read to the people. In the central division of the nave was also the *presbyterium*, a place enclosed and appropriated to the Deacons and Chanters, corresponding to the Choir of the present day: between the presbyterium and the entrance was the *narthex*, or, as it was afterwards called, the *Galilee*, a station assigned to the Penitents, to whom also, or perhaps to those who were more guilty than the rest, was allotted the portico on the exterior of the Church. One aisle of the Church was appropriated to the male, and the other to the female part of the congregation, these, in the ancient Church, being kept separate from each other. Over the aisles were generally galleries corresponding to those which, according to Vitruvius, were constructed in the Heathen Basilicæ; the arcades in front have been supposed to be intended to screen the people in the galleries from the rest of the congregation; but it is more probable that they were merely formed for the purpose of supporting the roof, where a horizontal entablature could not be obtained on account of the wide intervals of the columns.

The Constantinian Churches at Rome had generally, before the Western extremity, quadrangular courts with interior peristyles or arcades, as well for the Penitents as for the convenience of the congregation while waiting for the hour of prayer.

The transepts were probably added to the original rectangle in order to obtain room for a greater number of persons to get a sight of the High Altar, which was in the body of the Church; and in buildings thus constructed it was generally, though not always, placed at the intersection of the nave and transepts. In addition to this there was, sometimes, a smaller altar in the hemicycle at the Eastern end of the Church: the latter seems to have been the original place of the altar, the Bishop's throne only being behind it. Mr. Green, in his *History of Worcester*, supposes the other arrangement to have taken place when the doctrine of Transubstantiation was introduced in the Christian Church.

The Cathedral of Sancta Sophia.

The Cathedral of Sancta Sophia, at Constantinople, which had been built by Constantine, having been twice destroyed by fire, was rebuilt finally by Justinian about A. D. 532. His Architect Anthemius gave the design, and the Emperor every day superintended the work, which was completed in about six years from the time of laying the foundation: the magnificence of the edifice so well satisfied the Emperor that he is said to have glorified himself with the reflection that in it he had exceeded Solomon himself. For a plan and elevation, see pl. xiv.

The plan of the interior is that of a Greek cross, the four arms of which are of equal length; the central part is a square, the sides of which are each about 115 feet long. At each angle of the square, a massive pier of travertine stone has been carried to the height of 86 feet from the pavement, and four semicircular arches stretch across the intervals over the sides of the square and rest upon the piers. The interior angles between the four piers in the central square are filled up, from the springing points of the four arches, in a concave form, to a horizontal plane passing through their vertices, which are at 143 feet above the pavement; so that, at the level of the vertices, the interior edge of the part filled up becomes a circle, the diameter of which is equal to the side of the central square. Upon this circle, as a base, is raised the principal dome, the form of which is that of a segment of a sphere, which is said to be equal in height to one-sixth of the diameter of the base. On both the Eastern and Western sides of the square, in the centre of the Church, is a semicircular recess, the diameter of which is nearly equal to the side of the square · it is carried up to the same height as the piers, and terminates in a half-dome or quadrant of a sphere, its base resting upon the hemicylindrical wall of the recess, and its vertical side coinciding with the arch raised between the piers on that face of the building; the flat side of each recess and dome being open towards the interior of the Church. These quadrantal domes were intended to resist the lateral thrust of the arches raised on the Northern and Southern sides of the Church, but they were found insufficient, for the arches pushed away the half-dome on the Eastern side twice, and it could only be made to stand by constructing the great dome of pumice-stone and very light bricks obtained from Rhodes, by filling up the arches with others of smaller dimensions, and by carrying an enormous arch-buttress from a massive wall beyond the building to the foot of the dome.

At the extremities of the semicircular recesses, in a line running East and West through the centre of the Church, are smaller recesses, the plan of one of which terminates in a semicircle, and of the other in a right line; these recesses are built to the height of the springing of the four principal arches, and are crowned by quadrantal domes, which, as well as the recesses, are open towards the interior. In each of the two principal hemicylindrical recesses between the great piers and the other recesses just mentioned, are formed two other cylindrical recesses, open towards the interior and covered by quadrantal domes. All the recesses and domes are perforated by rows of small windows to obtain light.

On both the Northern and Southern sides of the square, in the interior of the Church, is a grand vestibule forming a square on the plan; the roof of each consists of three hemicylindrical vaults extending from North to South, and of another vault of the same kind crossing the former at right angles through the middle, and forming by their intersections three groined arches; these vaults are supported by massive pillars which have bases but no plinths; the upper part of their capitals resemble the volutes of the Ionic Order, but the lower part seems to be a barbarous imitation of the Corinthian base. Above these vestibules are galleries exactly similar to them, and, probably, appropriated to women during the performance of divine service. The whole Church is surrounded by cloisters and enclosed by four walls, forming one great rectangle on the plan.

The exterior does not correspond with the internal grandeur of the edifice, being surrounded by clumsy buttresses. The entrance is by a portico as long as the Church, and about 36 feet wide; this is ornamented with pilasters, and communicates with the interior by five doorways of marble, sculptured with figures in bas relief. Contiguous to this vestibule, and parallel to it, is another which has nine doorways of bronze.

After twenty years, the Eastern dome was thrown down by an earthquake, but it was immediately restored by the persevering industry of Justinian; and it now remains, after a lapse of thirteen centuries, a stately monument to his fame. Besides this Cathedral, Justinian is said to have built in Constantinople twenty-five Churches to the honour of Christ, the Virgin, and the Saints: he also built a Church to St. John, at Ephesus, and another to the Virgin, at Jerusalem, besides bridges, hospitals, and aqueducts in various parts of the Empire.

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The Christian Religion may be said to have rendered an essential service to the Fine Arts, as is observed by the Abbé Uggeri, (*Edifices de la Décadence*,) in having contributed to the revival of the genius of the artists after a period of barbarism, by the opportunity it afforded them of raising Temples worthy of the Divine Majesty; and to the preservation of many remains of ancient Architecture, which became embodied in the buildings they erected. While the Arts were tending fast to ruin, Constantine ascended the Throne, and under his protection were raised at Rome the works we have mentioned; the execution of which might have been impossible from the want of materials and workmen, if the fragments of the Heathen Temples had not furnished a supply of the former, and, in part, superseded the latter.

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The style of building employed in the Churches erected during the time of Constantine and his immediate successors would necessarily resemble that of the Basilicæ themselves; for the materials employed must have had an influence on the design, and columns taken from other buildings could only be applied in one which resembled that from which they came. And though some of the Basilicæ, which had been erected at an early period of the Empire, might equal in merit the best works of the Augustan Age, yet it is probable that most of them, and consequently the Churches of which they were the prototypes, were executed under the influence of that bad taste which characterises the Baths and Triumphal Arches. This is visible in a disregard of the proportions established by the more ancient artists, in a multitude of minute divisions and ill-executed ornaments destroying the simplicity which the designs of edifices of that class should possess. In several instances the columns which adorn the Churches have been taken from other edifices, either on account of the haste with which the buildings were constructed, or from incapacity on the part of the artists to execute any thing equal to them. These have been fitted to their places by the Procrustean expedient of cutting off the ends of those which were too long, or mounting on pedestals those which were too short; the rude artists seeming quite indifferent to the alterations which were thus made in the original proportions of the members of the Order. In some cases we find columns of different forms and proportions, not only in the same edifice, but in the same range, with bases, capitals, and entablatures mingled in the utmost confusion, and one substituted for another, seemingly because it came first to hand. A striking example of the capricious style which was occasionally employed in the ancient Christian edifices may be seen in the Tomb of Zacharias, at Jerusalem, a work of the time of Constantine. In its porch is a great torus moulding placed over a Doric frize, and above this is an Egyptian cavetto serving as a cornice.

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Amidst all this inattention to the principles of sound Architecture, a taste for that which might excite surprise by its magnitude and dazzle by its splendour prevailed in the East: to this taste we may ascribe the erection of the edifice of Sancta Sophia, which seems to have been intended to unite the characters of the Temple of Peace and of the Pantheon at Rome. An example of a magnificent, hemispherical dome already existed in the latter of those buildings, but this was raised on a cylindrical wall, and the horizontal thrust at its base, which is not considerable, could be counteracted by a sufficient hoop of masonry surrounding it; but the dome of Sancta Sophia is of a different character, and presents what must have been then a daring novelty, being raised on the tops of four piers; its form, also, is that of a flat segment of a sphere, consequently the horizontal pressure outwards at the base would be very great, and this could only be resisted by masses raised about the four piers: the difficulty of adjusting this resistance to the pressure, must, in those days, have been considerable, and it is not wonderful that the dome should have failed twice before it could be rendered secure.

The masses of materials which fill up the four angles in the interior of the building, to serve as supports for the base of the dome, are called *pendentives;* these, if we except the very small ones in the Palace of Dioclesian, are the first works of the kind with which we are acquainted, and their construction displays great skill in the Art of building.

The external effect of this dome is entirely lost by the enormous buttresses which prop it up, but persons who have seen it from the interior describe it as producing a most imposing effect.

Probable origin of high and narrow windows.

The hemicylindrical recesses, which were almost universally adopted in Religious edifices from the time of Constantine, may have led to the formation of the high and narrow windows, which also are found in many of those edifices; for the convexity of the wall would not permit broad windows to be made with either horizontal or arched tops, on account of the voussoirs projecting obliquely outward between their abutments; and, consequently, not being properly supported. Narrow windows are less subject to this evil, therefore such would naturally be preferred; and to obtain a sufficient quantity of light it would be necessary to increase their length in proportion to the diminution of their breadth. The windows of the Church of the Holy Sepulchre, at Jerusalem, are of this kind, with semicircular heads. This change in the form of windows seems to have been a step towards a greater change which, not long after this period, affected the whole style of Ecclesiastical edifices.

The construction of the Cathedral of Sancta Sophia seems to have been very generally adopted both in the West and East. At Corfu a small Church still remains which was built in the Constantinopolitan style, on the plan of a Greek cross, with a dome over its centre; and from an inscription over the doorway, it appears to have been erected in the VIIth century. The great Ecclesiastical structures of Italy, which were erected soon afterward, and even the Mosques of the Mohammedans, present nearly a similar appearance.

We terminate here our account of the Architecture of the Roman school. From the time of Justinian an entirely new manner of building arose, which gradually superseded the former, and for several Ages prevailed universally in every Country which had been subject to the Roman dominion.

CHAPTER X.

Arabian or Saracen Architecture.

Departure from the Greek and Roman Architecture.

We have now arrived at a time when a considerable change took place in the Architecture both of the East and West: instead of the Grecian and Roman porticos with their long, horizontal entablatures and pediments of low elevation, we find arcades supported on very massive or very slender columns, and lofty roofs crowned by cupolas; and instead of that majestic simplicity of building which, in general, was indebted only to the correctness of its proportions for the admiration it excited, we find an effort to produce surprise and extort applause, by boldness of form and a profuse display of elaborate and fantastical ornament.

But the new styles which arose in the East and West, though possessing some points of resemblance, differ materially from each other; and as the latter suffered several modifications in different places and in process of time, which it will be advantageous to pursue in an uninterrupted course, we think it convenient to describe, first, the Architecture of the people of the East during the decline of the Constantinopolitan Empire; in order that nothing may interfere with the account we purpose to give of the rise and progress of those styles of building which then, and afterwards, prevailed in Europe.

The Kaaba, at Mecca.

Those Sciences of which the Arabs, or Saracens, from the earliest times were in possession, they probably learned from their Egyptian and Babylonian neighbours. Strabo informs us that they had magnificent Temples and private dwellings built in the Egyptian style, and a Temple, at Mecca, is mentioned by Diodorus as existing in his time; we are ignorant of its form, but it was rebuilt, or, at least repaired, by Mohammed, and became the chief Temple of his Religion. This is now called the *Ka'beh*, or Square building, and a description of it will be found in our *Miscellaneous Division*, under HEDJAS. It is likely enough that this building, originally, did not differ much from an ancient Egyptian Temple; and it is also reasonable to suppose that the cupolas and turrets which rise above the roof were imitations of similar works erected in Syria by Justinian or his successors; or they might have been at once adopted from the Cathedral of Sancta Sophia itself; of which the Arabian Prophet might have been informed by those who are said to have assisted him in compiling the Koran.

Mosque of Omar, at Jerusalem.

On the ruins of the ancient Temple at Jerusalem, the Caliph Omar, about A. D. 640, raised a superb Mosque, which, by the Mohammedans, is considered as next in sanctity to that at Mecca, and of which, till lately, no particulars were known to the Christian world. We are indeed still ignorant what was the nature of the edifice originally erected by Omar, because many additions have been made to it, at subsequent periods; but the following account of it has been drawn partly from the *Itinéraire à Jérusalem*, by Chateaubriand, partly from other sources.

The whole is contained in a quadrangular area, about 500 paces long and 460 paces wide, surrounded by walls in which are twelve entrances through as many porticos at unequal distances from each other, and consisting of arcades supported on pillars in one or two tiers; and it is probable that the high towers about the building, mentioned by William, Archbishop of Tyre, were situated at the angles of this enclosure. On the exterior of the wall, towards the East and South, are the walls of the city; on the West are some Turkish houses; and on the North are the buildings called the *Prætorium* of Pilate, and the Palace of Herod.

The edifices within the enclosure consist of two Temples, or Mosques, called respectively *El Achsa* and *El Sachara;* the former is divided into seven aisles by rows of cylindrical columns, each 16 feet high and 2½ diameter; these support arches each formed by two segments of circles meeting in a point at the vertex, but the whole differing little from a semicircle. Above the arches are walls 13 feet high, and pierced with two rows of windows; at one extremity of the central division are four piers disposed at the angles of a square on the plan, and surrounded by marble columns; and from the piers spring four arches, above the crowns of which is a cylindrical tambour 32 feet diameter, containing two rows of windows, and supporting a dome in the form of a segment of a sphere, the interior of which is ornamented with gilding and painting of that kind which has been since called arabesque. Near this edifice, and within the enclosure, is a terrace 460 feet long, 400 feet broad, and raised 6 or 7 feet above the court, from which there is an ascent on each side by marble steps: in the centre of this platform is situated the Mosque *El Sachara*, a building of an octagonal form; and, according to the information given by the Turks to Deshayes, containing in its centre the stone or portion of rock on which Mohammed mounted when he ascended to Heaven. About this stone, are four piers surrounded by columns supporting an octagonal lantern, and crowned by a dome similar to that of El Achsa; this was formerly covered with gilt copper, which the Caliph El Louid had taken from a Church at Balbec, and it is terminated above by a spire and crescent. The walls of this building are faced on the exterior with little squares of coloured bricks and marble, and ornamented with arabesques and texts of the Koran; and in the lantern are round windows of coloured glass. There is said to be an entrance on each face of the Mosque, and each doorway is ornamented with mouldings and columns. The columns of the interior, which are placed on pedestals, and crowned by capitals, have probably been taken from Christian edifices.

Mosque near Cai

We may add to the above account of the Arabian edifices, that there exists an abandoned Mosque, seemingly of ancient date, near the walls of Cairo. According to the description given by Pococke, it must have resembled that at Jerusalem; at the angles are square pavilions which terminate in minarets, and along each face is a row of arches with pointed vertices; the walls are crowned with battlements of a triangular form, having each side cut to resemble steps. In the centre of the building is a square tower with a polygonal lantern crowned by a cupola, the form of which is that which would arise from the revolution of a pointed arch about its vertical axis. From certain inscriptions in the Cuphic character, the origin of the building is referred to some period more remote than the Xth century, but this is extremely uncertain.

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Considering the great extent of the dominions acquired by the Arabians shortly after the establishment of the Religion of Mohammed, the magnificence of the Courts of Cairo and Bagdad, and the patronage bestowed by the Caliphs on men of Science, it is surprising that so few public buildings should remain, the construction of which can be referred to the times in which those Princes flourished. We can hardly ascribe this scarcity to any devastations produced by the wars which subsequently took place in that part of the World; for except the Crusaders, whose conquests did not extend much beyond the sea-coasts of Syria, and who alone from Religious motives might have destroyed the buildings of their enemies, all other invaders of the Empire of the Saracens were men of the same Faith with themselves, and would naturally consider the public edifices erected by the Caliphs as property common to all the Moslems. But whatever be the cause, it is certain that, except the Mosques at Mecca and Jerusalem, nearly all the remains of the Architecture of the Eastern Saracens have disappeared.

Tomb Abda

Of the few that are still in existence we may mention the Tomb, said to be of Abdallah, one of the twelve disciples of Mohammed. According to the description of Cornelius Le Brun, its plan is a square of 32 feet, and the entrance is in front at an aperture covered by an arch formed of two segments of circles meeting in a point at the top, the radii of which are about equal to the span of the aperture. If this Tomb were really erected immediately after the death of Abdallah, it would afford an important evidence in favour of the Saracenic origin of the species of arch with which it is ornamented; but this is extremely improbable.

The same species of arch occurs also in the Castle of Cairo, and in the ruins of an edifice, in the same city, called the Hall of Joseph; both of which are supposed to have been works of Saladin. The latter is a quadrangular area surrounded by tall columns of porphyry, or granite, without bases, but having circular plinths; the capitals resemble those of the Corinthian Order, but are more simple; and from them spring arches with pointed tops, like that above mentioned. The uncertainty, however, respecting the period during which these edifices were erected, does not permit us to consider them as affording any data by which to determine the antiquity of the pointed arch; a member which, as we shall presently see, forms so distinguished a feature in the Architecture of Europe during what are called the Middle Ages.

The Empire of the Saracens extended from the banks of the Indus to the Western extremity of Europe, and it is a remarkable circumstance that the most splendid specimens of their Architecture should be found so remote from the seat of their Government as Spain; in fact, the principal building from which we derive our knowledge of the Arabian Architecture is the Mosque at Cordova, for a description of which we are indebted to Mr. Swinburne. It was begun in the year 786 by Abdoulraham, King of the Moorish dominions in Spain; and the style of it was, no doubt, copied from such Arabian buildings as existed at that time in the East. It is a large rectangular edifice, 510 feet long from East to West and 420 feet broad, and is divided into two parts by a wall parallel to its greatest length. The Northern part is an open court in which the worshippers performed their ablutions previously to their entrance into the body of the Temple; its length from East to West is equal to that of the whole building, and its breadth is 240 feet; a covered colonnade, 25 feet wide, consisting of sixty-two pillars, occupies three of its sides in the interior, and on the fourth is the wall before mentioned, in which are several doors communicating with the other part, which may be considered as the main body of the Mosque.

This latter part is divided into seventeen aisles by nearly a thousand columns of various-coloured marble, disposed in rows extending from East to West, and about 20 feet asunder. Of these rows there are two, consisting of columns attached one to each face of a square pier. These cross each other at right angles, and divide the Mosque into four rectangular portions, three of which were allotted to the populace, and the fourth, which was the South-Eastern quarter, contained apartments for the Priests and Nobility, and the thrones of the Caliph and Mufti. All the columns are about 18 inches diameter, but they are not of the same height, and seem to have been taken from Roman buildings, which, probably, at a more ancient time, existed in the neighbourhood; those which were found too long for the purpose had their bases cut off, in order to reduce them to the required size; others, which were too short, were lengthened by giving them tall capitals, cut to resemble those of Corinthian columns, but badly executed. The aisles are covered by low vaults, and an arch, in the form of a segment of a circle, springs from the top of every two columns in the direction of the length of the building. The interior receives light chiefly from the doorways, and from apertures in the roof.

The exterior walls of the Mosque are plain, and the roof is hid from view by battlements cut in the shape of steps. The Eastern wall is supported by buttresses, and, on this front, are several semicircular-headed windows, with archivolts springing from short pilasters or columns, approaching the Tuscan form; some of these windows are double, and consist of two semicircular-arched tops, which rest upon three short pillars. The doorway is crowned by an arch composed of two segments of circles meeting in a point at top, and continued below the horizontal line passing through their centres; so that the aperture at the foot of the arch is less in breadth than at some distance above it; a form which, though not always assumed by Moorish arches, has never been employed in those of any other people

Bath at Gerona.

At Gerona, in Catalonia, are the remains of an Arabian Bath, of considerable, though uncertain antiquity, but deserving mention in this place, as it is the only known example of a species of building which must have been as generally constructed by the Arabians as by the Greeks and Romans. It consists of a square apartment, having in the centre a space enclosed by a low octagonal wall, on the periphery of which were placed eight columns, with capitals resembling those employed in the ancient Egyptian Architecture. From these capitals spring eight arches in the form of segments greater than semicircles; a kind of arch which, from its resemblance to a horse-shoe, is generally called by that name. These support an octagonal wall, from which spring cylindrical vaults to the four sides of the apartment, and to four faces formed diagonally at its interior angles. Above the wall is an open lantern formed by eight short columns, which support an octagonal cupola with a pointed vertex. In one of the sides of the room are recesses, the entrances to which are crowned by pointed arches.

The Alhamra at Grenada.

We may conclude this account of the Saracenic buildings by a reference to the description of the ALHAMRA, or Palace of the Moorish Princes of Grenada, given in our *Miscellaneous Division, ad v.* This edifice, though it was not erected till near the end of the XIIIth century, appears to have been built according to the same style as the earlier works of the Arabians, but with a greater degree of ornament.

Elevations of a column and one of the arches in the Court of the Lions there described, are given in pl. xv.

Character of the Saracenic Architecture.

The Arabian or Saracenic Architecture seems to have undergone some change during the time in which that people enjoyed a political existence. The style of the original examples has some resemblance to that which prevailed in the Byzantine Empire. The cupolas formed in the earliest buildings are probably copies, on a small scale, of those which crown the Church of Sancta Sophia; and, of the columns which were employed in the same buildings, those not actually taken from edifices of more ancient date, were formed, though rudely, in imitation of such as had been executed by Roman artists. The later style of the Arabians seems to be distinguished by cupolas formed of portions of cylinders springing from a square or octangular base, and meeting in a point at top, like what are called cloistered vaults; by arches in the form of segments greater than semicircles; by slender, square minarets, terminating in a ball, or pine-apple; and by the painted tiles and mosaic work with which the walls of the buildings were covered.

The buildings we have described are those which have first given us occasion to introduce the cuspid arches, or those formed by segments of circles meeting in a point at the vertex; and could we be certain that they were constructed at the time of the erection of the oldest buildings in which they are found, there would be no hesitation in admitting that they are the originals of that kind of arch which from the XIth to the XVIth century prevailed almost universally in Europe. Considerable doubt, however, is thrown by travellers, on the antiquity of those arches, and it is generally believed that the date of their construction is posterior to that of the buildings themselves; and, consequently, they afford no proof that the Arabians have a just claim to the invention of the pointed arch. With respect to those of the horse-shoe form, there is little difficulty in admitting that they may have been the inventors of it, as no example of a precisely similar form is to be found in any part of Europe, except Spain. This construction must have originated in the mere love of novelty; for the least attention to its form will show that it does not possess the essential property of an arch, stability, since the pressure in the direction of the curve is entirely unresisted at the foot; and therefore, the wall over the aperture is prevented from falling only by the means employed to bind together the stones, both in the arch and the wall above it.

In Saracenic arches we find the adjacent sides of the voussoirs cut in notches, like the teeth of a saw, the projections of one fitting the rentrant parts of the other; a construction which indicates an apprehension on the part of the builders that plain sides would not have had sufficient divergency to permit the blocks to keep their places. But this serrated form subsequently became a species of intricate scarfing, the projections and the corresponding notches being cut in the form of complex curvilinear mouldings; these might have been introduced merely for the sake of ornament; but it is also possible that it was intended to unite all the voussoirs together, so as to constitute an archivolt capable of standing vertically without any lateral pressure; this, in the horse-shoe form, must have been an object of importance, as there is nothing to counteract the inward pressure at the lower extremities of the arch.

The Moorish arches about a doorway are frequently ornamented in the most splendid manner; the faces of the voussoirs are marked with arabesques, and surrounded by a moulding, which is not, in general, concentric with the intrados; the whole is enclosed in a rectangular panel, the mouldings and surface of which are elegantly enriched with scrolls and foliage; and commonly, the foot of the arch rests on a small column on each side of the aperture. In pl. xv. is given an elevation of part of the highly ornamented entrance to the Sanctuary of the Koran in the Mosque at Cordova; this may, perhaps, be considered as the richest example of the manner in which the Arabian artists embellished their edifices.

The Religion of Mohammed forbidding the representation of animals, the sculpture of the Arabians consists of foliage, or texts of the *Koran* inscribed on the walls. To the first they gave every variety of form that the most fertile imagination could devise; and hence, all ornaments of a fantastic character have, from this people, obtained the name of *Arabesque* or *Moresque*.

M. Durand observes that the Mosques of the Arabs contain, in a quadrangular enclosure, an immense quantity of columns ranged in files like plantations of trees, among which the people might enjoy that coolness, which, in the climates of the East and South, was not to be obtained in the open air; and M. Chateaubriand perceives, in the heavy, majestic, and durable style of Egyptian Architecture, the germ of the light Saracenic; he considers the minarets as imitations of obelisks; the arabesques as hieroglyphics painted instead of sculptured; and he gives the Temples of Egypt as examples of the forests of columns composing the interior, and bearing the flat roofs of the Arabian Mosques. But it may be observed that, with this sort of license, no difficulty need be experienced in justifying any hypothesis whatever.

The minarets, or lofty slender turrets, which always accompany the Religious edifices of the Mohammedans, are supposed by D'Herbelot to have been first erected by the Caliph Walid about the beginning of the VIIIth century.

PART III.

GOTHIC AND INDIAN ARCHITECTURE.

CHAPTER I.

Ecclesiastical Architecture of Italy before the XIVth Century.

We revert now to the Architecture of Europe; and, taking it up at the time which immediately followed the erection of the Cathedral of Sancta Sophia, at Constantinople, we proceed to trace in Italy, and subsequently in the North of Europe, the imitation of the style exhibited in that edifice; and, finally, to develope the character of a style of unknown origin, the principal features of which differ considerably from those of any edifice before constructed.

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The introduction of the arch seems to have been the first step towards that complete change which took place in Roman Architecture at the time of the decline of the Empire. In the ancient buildings the columns employed to divide the internal area, or to support the roof, had their distances from each other necessarily regulated by the length of such stones as could be procured to form the entablature, since the extremities of each stone were to rest on the two nearest columns, or upon other stones which project but little beyond the interior sides of those columns. But an arch, the extremities of which were supported on two piers, could be made to cover an interval more considerable than the extent of a regular intercolumniation; and, therefore, would be a great improvement in a public building where the frequency and closeness of the columns would render it impossible for the eye of a spectator to command a good view of the interior. As soon as this construction had been adopted, it would not, probably, be long before an effort would be made to diminish the massiveness of the piers, which, as the arches counteract each other's lateral pressures, have evidently to support only those in the vertical directions. It is, therefore, conceivable that the next step would be to make the arch rise from the top of a column. The arcades thus formed constitute one of the principal features of the style which succeeded the ancient Roman, and in the above manner their origin may be accounted for.

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Another feature is that which is called groined vaulting, a species of covering which could not escape the notice of any person who had been employed to execute a common cylindrical vault; since the intersection of two such vaults would produce that particular kind of which we speak; and the idea being once obtained, the method of construction would be sufficiently obvious.

At first the diagonal ribs of the groined vaulting may have been made to rise from the interior angles of the walls of a building, or from the square piers left by the intersections of the passages which cross each other at right angles within the area; but the employment of columns to support simple arches, subsequently led to the practice of making the ribs of the groins rest also on the columns. The modifications of this system of arches and vaults springing from pillars, constitute the differences in the character of that species of Architecture which we are presently to consider.

The communication between Greece and Italy favourable to Architecture.

The intercourse which subsisted between Italy and Greece after the fall of the Western Empire, gave rise in the former Country to specimens of Architecture and Sculpture of the purest kinds, long after the irruption of the Northern Nations had annihilated the Arts and artists in other parts of Europe. The merchants of Venice, Genoa, and Pisa, together with the natural productions and manufactures of Greece, imported from that Country the materials of its ancient buildings, with which they adorned their own cities; and from the dearth of artists which then prevailed in the rest of Europe, natives of Greece are supposed to have been employed to construct the Ecclesiastical edifices of Italy with the ruins of the Temples of their Heathen ancestors. It is thus that in the IXth, Xth, and XIth centuries, the Cathedrals of Venice and Pisa and the old Church at Ravenna were built, by artists from Constantinople, or by Italians formed in their school, in imitation, and according to the disposition of the Cathedral erected by Justinian, in the latter city; but with members which bear the marks of the good taste of the ancient Greeks. Even where such materials were not actually employed, the imitations of them would be less unworthy of the ancient masters than the rude works of persons left to the indulgence of imagination, without taste or skill to guide them in the design or execution of their own fantastic conceptions.

Extension of the old Italian Architecture to the North of Europe.

The Ecclesiastical Architecture of Italy would naturally be carried into the Northern part of Europe by the Clergy of the different nations of Christendom, who, from the time that the Papal influence became general, visited Rome on a spiritual or a temporal account. These persons would observe the style of building in that city, and take delineations of the edifices; by these they would erect similar works in their respective Countries, with such variations as their several tastes might dictate; and hence, though there would be a general conformity with the Italian models in the outline of their edifices, yet the details may be expected to vary considerably. This is, no doubt, the reason of the differences in style observable in the Churches of Germany, France, Spain, and Britain, which some have considered to be as strongly marked as those in the Doric, Ionic, and Corinthian Orders. In those Countries the artists, having before them few examples of the antique Roman Architecture on which to form their taste, were naturally inclined to improve upon the contemporary style of Italy, which had been transplanted thence in the way we have described. This improvement they continued till they raised out of it another style, very different, but perhaps equally beautiful with that from which it had, at first, degenerated.

The Ecclesiastical edifices which, in Italy, have been executed according to the style so prevalent in the

Causes of the small influence of the Northern Architecture in Italy.

North of Europe from the XIIIth century, are probably modified imitations of the Cathedrals of Germany and France. The Architecture of these buildings may have been introduced into Italy by the power of example, and in spite of the monuments of Roman Art on which the taste of the Italians had before been formed. But these monuments being far more numerous in Italy than in the North of Europe, it is easy to perceive that such a predilection for the antique would exist in the former Country, that the Northern style would hold but a subordinate rank. And when, at the revival of the Arts, the Roman Architecture was more diligently studied in Italy, it became a standard for the buildings subsequently erected in that Country, and the Architecture of the Dark Ages, which appeared to be a corruption of the former, was held in contempt. Finally, in the XVIth century, the artists of Italy succeeded in bringing the Architecture of the rest of Europe within the pale of the Roman school.

Impropriety of the terms Gothic,

The style of building which prevailed in Europe from the fall of the Roman Empire till the XVIth century is classed under the general name of *Gothic*, as if it had been invented or introduced by the Goths in the different Countries which they conquered. Nothing, however, it must be owned, is more erroneous than such an opinion; for the Barbarians who overwhelmed the Empire do not appear to have had either the inclination or the means to execute any one of those works which are called by their name. Indeed History informs us that when the Goths adopted the Religion and the manners of the polite Nation which they had subdued, they adopted also its style of Architecture, and built Churches according to the examples which they saw in Rome; which they, most probably, would not have done had they possessed any thing like a style of building peculiar to themselves.

and Saracenic Architecture.

It has been proposed to apply the term *Saracenic Architecture* to that style which prevailed in Europe from the Xth to the XVIth century; from an opinion that its principal features were derived from those employed in the Architecture of Syria and Egypt about the commencement of that period. This opinion, and with it the name, is now abandoned. It is true that the Arabs or Saracens brought a particular style of building into the South of Europe, which, no doubt, was either identical with, or a modification of that which had, perhaps, long prevailed in the East; but the Arabian Architecture differs considerably from that which prevailed in the North of Europe at the same time, and the latter appears to have been a gradual developement of some preexisting mode, which would not be the case if it had been adopted at once from that of the Orientals.

The *Architecture of the Middle Ages*, and the *Christian Architecture*, are terms which have been also applied to the class of buildings now under consideration; but, though not destitute of propriety, they are yet liable to some objections. The first because its application will, in the course of time, cease to be just; as the period of its existence will not be a Middle Age for a remote posterity. And with respect to the other term, it may be thought to comprehend too much, for the sacred buildings of the Christians have not been confined to this, nor to any other particular style; they were first constructed in the manner which prevailed in Italy when the Arts were at a low ebb, and subsequently in imitation of the purest style of the edifices of Rome and Greece.

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To the Architecture of Europe in the period before mentioned, the term Gothic seems to have been given by those professional men who have since laboured to revive the Architecture of ancient Rome, as a mark of reproach, indicating that it was as destitute of architectonic merit as the Goths were of Science; and though those persons probably were mistaken, and their censure too severe, yet, as the term has now become general, it will answer the purpose of distinction as well as any other; and may, therefore, be employed, provided we agree to consider the style to relate to the Goths no otherwise than as the first specimens of it existed in Europe about the time when that people performed an important part on the same theatre.

Different classes of Gothic Architecture

The division which the Italians made of the general Gothic style seems sufficiently proper, and shows, at the same time, the Countries in which the distinguishing characters originated. That particular style which prevailed in the North of Italy, they called Lombard Gothic, *Gotico Italico;* that which prevailed on the North of the Alps, they called German Gothic, *Gotico Tedesco;* and that in Spain and some other Countries, they called Arabic or Moorish Gothic, *Gotico Moresco.* In England, where different styles prevailed at different times, and the features of each are strongly marked, it is considered as of three kinds; *viz.* the *Saxon* and *Norman* Gothic, the *full* or *simple* Gothic, and the *florid* Gothic. This last style had hardly arrived at perfection when taste suddenly made a revolution in favour of the ancient Roman style, and the Gothic Architecture was completely abandoned. A different classification has been made of the ancient English Architecture by some writers on the subject. The Saxon is considered as a style distinct from the Norman; and that which succeeded, and which is designated by the general term *Gothic*, is divided into the *lancet-arch* Gothic, the *complete* Gothic, the *ornamental* Gothic, and the *florid* Gothic; but the Norman style seems to be only a modification of the Saxon; and the epithets applied to the others sufficiently indicate that these differ only in the degrees of ornament applied to the same or similar features; and, therefore, that the distinctions are hardly necessary.

It is probable that between the VIth and Xth centuries, the Ecclesiastical edifices of Italy were imitations either of the ancient Basilicæ, or of the Cathedral at Constantinople, and the few remaining Churches of that time have evidently been formed upon the model of the last-mentioned building; hence these edifices are considered as belonging to the *Constantinopolitan*, or, as some call it, the *Greco-Italico* style. After the Xth century, the characters of the Eastern and Western basilican Churches seem to have been united, and the style thence resulting is that which is usually designated the *Lombard* Gothic.

Cathedr
St. Mark
Venice.

The greatest of the Italian Churches built in the Constantinopolitan style, is the Cathedral of St. Mark, at Venice, which is said to have been erected in the IXth century by a Greek artist whose name is unknown. Its plan is that of a Greek cross, and each arm is roofed with a hemicylindrical vault; these meet in the centre of the building, and terminate in four semicircular arches on the sides of a square about 42 feet long in each direction. From the angles of the piers between these arches rise pendentives, similar to those of Sancta Sophia, and terminating at top in a circle which forms the base of a cylindrical wall; in this is contained a row of windows to give light to the interior, and on it is raised the central or principal dome, which is of a hemispherical form. The Church is divided, longitudinally and transversely, by rows of columns supporting semicircular arches; and the aisles of the body of the building and of the transept intersect each other in four places about the centre of the cross; over these intersections are constructed domes similar to that of the centre, but smaller, so that there are five domes on the roof of the Cathedral; the exteriors of the domes are covered with lead and surmounted by crosses.

The façade of St. Mark consists of three stories: in the centre of the lower one is the entrance, which is covered by a great semicircular arch, and on each side are two other arches of the same form; all these have plain archivolts, which spring from the upper of two Orders of columns placed one above another. At each extremity of the façade is a square tower, in each face of which is an arch, supported also on the upper of two Orders of columns. Over the lower arcade is an open platform, with a balustrade which is continued round the exterior of the Church; in front of this platform, and occupying the centre of the façade, are the four famous horses of Corinthian metal, which once belonged to the Arch of Nero.

The second story contains four blank semicircular arches, placed two on each side of a central aperture, which is higher than the four arches and forms a window; all of them are covered by pediments in the form of curves of contrary flexure, and ornamented with foliage; and over the spandril between every two arches is a turret terminating in a small pyramid or pinnacle. The building has undergone many alterations since its original construction, and the ornaments just mentioned are certainly of much later date than the rest of the edifice. The general style, however, seems to have been constantly preserved.

The Campanile or Bell-tower of St. Mark, which was built by Buono, an Italian architect, in 1154, is a brick building, the plan of which is a square, 40 feet in extent in each direction, and which rises to the height of 330 feet. It is celebrated for its strength and firmness, not having declined from a vertical position as so many other similar buildings in Italy have done.

In Certosa, one of the Islands of the *Lagune* at Venice, is a Church, erected, as appears by an inscription, in 1108, which on account of its great antiquity, and for a certain singularity in its interior, deserves to be mentioned in this place. The plan is a simple parallelogram, having no transepts, but at one end is a hemicycle or semicircular recess, in the centre of the curvature of which is the altar; concentric with the curve of the wall, and rising gradually towards it, are rows of seats like those of a Theatre. A flight of steps proceeds from the back of the altar, in a direction parallel to the sides of the building, to the level of the uppermost seat, where was situated the throne of the Bishop. The body of the Church is divided longitudinally into three parts by two ranges of columns which support arches taller than semicircles, the curvature of the archivolt commencing at a small distance above their capitals. The height of the throne is such that, when the Bishop was seated, his head must have been on a level with the tops of the same columns.

The Church of St. Vitale at Ravenna, which was built probably about the same time as that of St. Mark, is nearly in the same style. The exterior walls are formed upon a regular octagon, the diameter of which is 128 feet; within these are eight piers disposed at the angles of an octagon concentric with the former, and 54 feet in extent from one side to that opposite. The height of these piers is 55 feet; above them, and crowning the whole edifice, is a hemispherical vault covered by a conical roof of timber. This dome is remarkable for the spandrils being filled with empty vases of potters'-clay, and round the exterior of its base are semicircular-headed windows, each of which is divided into two apertures of similar forms. Between every two piers is a hemicylindrical recess formed on each side of the octagon, and covered by a half-dome, the vertex of which is 48 feet from the pavement; each of these recesses contains two windows divided into three parts by two Corinthian columns supporting semicircular-headed arches. Between the piers and the exterior walls of the building are two corridors surrounding the whole, one above another, and each covered by a hemicylindrical vaulting. The upper corridor has a sloping roof of timber above the vault.

of St. Anthony, at Padua.

The Church of St. Anthony, at Padua, is in a mixed Gothic style, and is crowned by domes like that of St. Mark; but this building is particularly distinguished for two slender towers or minarets, which give it much the air of a Saracenic edifice.

The Cathedral at Pisa.

The Cathedral at Pisa, with the Baptistery and Belfry belonging to it, form a group of buildings not only the finest in Italy, but possessing in an eminent degree those features which particularly distinguish the Lombard-Gothic style of Architecture, and, therefore, claim a particular description. The Cathedral was built, in 1016, by Buschetto, a Greek or Italian artist, for it is uncertain which; its plan resembles a Latin cross, of which the principal part is 304 feet long, and 107 feet wide; and the transverse branch is 234 feet long, and 55 feet wide. The former is divided longitudinally into five parts, of which the grand nave is 40 feet broad, and 128 feet high; this is separated from the nearest lateral aisles by twenty-four Corinthian columns of Oriental granite, of which there are twelve on each side. Semicircular arches spring from the capitals, and carry smaller columns forming the front of an upper gallery appropriated to the women. The columns which separate the lateral aisles are smaller than those of the nave, but are raised on pedestals to an equal height. The nave is roofed with timber, but the aisles are vaulted and painted. The transept is composed of a nave 107 feet high, and two aisles, each 60 feet high, and formed by columns of the same size as those of the aisles before mentioned. In the intersection of the naves are four pillars supporting four great arches, above which is a polygonal wall adorned with eighty-eight columns supporting arches, and on this rests a corona of marble; above the corona is a cupola 70 feet high, the interior of which is lighted by one hundred windows The exterior of the wall on which the cupola is built is ornamented with two tiers of arches, of which those in the upper tier are small and crowned with decorated pediments with pinnacles between them; but these are probably of later date than the original structure.

The Western façade consists of five stories; the lower one is composed of seven arches supported by six Corinthian columns and two pilasters; the second contains nineteen arches, supported by eighteen columns and two pilasters; the third has nine arches in the centre, all of equal height; but on the right and left of these, where the façade is limited by the sloping roof of the galleries over the aisles of the nave, are columns which diminish in height according to the inclination of the roof. The walls of the central division of the nave are carried vertically above the level of these roofs, and terminate in a roof with sloping sides, forming a longitudinal ridge in the middle, and the corresponding part of the façade is ornamented with two tiers of arches, supported by columns as in the tiers below; the arches in the upper tier are supported by columns, which also diminish from the centre towards the extremities, on account of the inclination of the sides of the roof. The sloping sides of the pediment or gable are ornamented with foliage, supposed by Dr. Milner to have been added when the Cathedral was repaired after the fire of 1569, which burned down the roof from the cupola to the Western end. The arches and columns in the lowest tier of the façade are attached to the wall, but all those above are detached from it, and have a narrow open gallery in their rear.

Along the exterior of the walls of the nave and transept are three tiers of attached arches and pilasters, corresponding in situation with the lower, the second and fourth tiers of the façade. In the middle of the Eastern end of the Cathedral is a semicircular projection towards the exterior, ornamented with three tiers of arcades corresponding also with those of the Western front; this projection terminates at the height of the roof of the aisles, above which this face of the building is flat; it is ornamented with two tiers of arches, and terminates in a gable. Similar projections are formed at the extremities of the transepts. The whole edifice stands on a basement which is ascended by five steps. In pl. xvi. is a perspective view of this Cathedral. See also a superb Work on the Architecture of the Middle Ages, by Cresy and Taylor.

The Baptistery, at Pisa.

The Baptistery, which was begun, in 1152, by Diotti Salvi, is a cylindrical building of marble, 129 feet in diameter, and raised on three steps. On the exterior, are two Orders of Corinthian columns engaged in the wall, and supporting semicircular arches; the columns of the upper Order are more numerous than those of the lower, each arch below bearing two columns above it. Between every two arches of the upper row is a pinnacle; above each arch is a sharp pediment enriched with foliage, and over these is a horizontal cornice surrounding the building. Above the second story is a cylindrical part ornamented with semicircular arches, crowned by pediments; and between the arches are pilasters which carry a horizontal cornice like the former; over this is a pear-shaped cupola, 179 feet high, and covered with lead. The convex surface of the dome is divided by twelve ribs of copper which unite at the vertex, and these are ornamented with knots of foliage, or, as they are called, *crockets*, executed in marble; between every two ribs are windows ornamented with little columns and terminated by small open pediments. The whole forms a mixture of the round and pointed styles of ornament; the features of the latter, *viz.* the pinnacles and pediments, are generally supposed to have been introduced subsequently to the original construction of the edifice; but this seems doubtful, except so far as concerns the decorations which accompany them.

The dome is double, being composed of two shells, and the interior one is a frustum of a pyramid of twelve sides; its upper extremity forms a horizontal polygon, which is finished with a small parabolic cupola, having twelve small marble ribs on the exterior. The outer vault is of brick, of a hemispherical form, terminating above at the base of the small cupola, which, like a lantern, stands over the aperture. The height of the cupola from the pavement is 102 feet. The entrance to the Baptistery is by a grand doorway, and there is an interior descent by three steps round the building; the space between the steps and the wall was for the accommodation of the persons assembled to witness the ceremony of baptism.

Round the interior circumference of the Baptistery is an aisle or gallery, formed by eight granite columns and four piers, from which spring semicircular arches supporting an upper gallery; above this tier of arches, are twelve piers, on which rest the semicircular arches supporting the pyramidal dome. On the ground story are four entrances, and between each two, on the exterior, are five columns; that story is, therefore, surrounded by twenty. The capitals of these columns support semicircular arches decorated with foliage; above is a second story with semicircular arches, in the same style, resting on piers and leaving a gallery behind them which forms a walk round the building.

Mr. Cresy states, in Britton's *Architectural Antiquities*, vol. v., that above the floor of the inner gallery is an inscription showing that this part was rebuilt in 1278; the same gentleman adds, that the mouldings of the interior correspond with those of the Campo Santo built at that time by John of Pisa, and that one of the shields on the windows of the dome bears an inscription, dated 1396, to the memory of the operarius or architect; and he attributes to this person all the work in the pointed style, together with the domes.

The Cam nile, at Pi

The detached Tower or Belfry, which was built, in 1174, by two Architects, an Italian and a German, is of a cylindrical form, 50 feet diameter, and 180 feet high, and consists of eight stories of columns supporting semicircular arches, forming as many open galleries. It has a flat roof, and the upper story contains a peal of bells. A remarkable circumstance in this Tower, as well as in several other Italian Belfries, is that they have sunk on one side considerably; in the present instance so much that the top overhangs the base about 13½ feet. There is no doubt this has been caused by a defective foundation, and that it sank when only partly erected; for, on one side, at a certain height, the columns are made higher than on the other side, showing that the builders, after the failure, endeavoured to bring the upper part of the Tower nearer to a vertical direction. See pl. xvi.

The Ca Santo, Pisa.

The Campo Santo, or public burying-place, at Pisa, was built, in 1278, by an Architect of that city. It is a great quadrangle, 403 feet long, 117 feet wide, and surrounded by a corridor 32 feet broad on the interior of the enclosure, in which the bodies of the dead are deposited; the corridor is roofed, but the interior area is open to the sky; in the side of the corridor next to the area are semicircular-headed windows, which at first were simple apertures extending down to the pavement, but each has been subsequently divided into smaller apertures by vertical columns, which from the level of the foot of the arch form intersecting ramifications. These enrichments have been added to the structure by some later Architect; probably by Burgundio Taddi, who, in 1303, added new members to the exterior of the building; or by Antonio Jacopo, a Pisan Architect, who, according to an inscription on the North side, executed four open arches and twenty-eight windows, in 1464.

The Cathedrals of Orvietto and Sienna, the Churches of St. Francesco, at Pisa, and of St. Michael, at Lucca, are all similar in form and general style to the Cathedral at Pisa.

thedral at enna.

The Cathedral of Sienna, however, is distinguished by a mixture of the circular and pointed arches; and, therefore, resembles in some respects the Gotico Tedesco. Its construction is marked by some singularities; the centre of the dome is not over the centre of the intersection of the nave and transept, but is nearer the Western end. The dome itself, which has a pointed vertex, is raised upon a base of twelve sides, and this is supported on six pointed arches formed over a hexagonal plan.

e Cam- nile at cca.

The Bell-Tower, at Lucca, is a perfectly square prism, consisting of five stories in height, of which the three lower are ornamented respectively with one, two, and three semicircular-headed windows; over the windows in each story are small semicircular-headed ornaments like arches, and the upper story is crowned with notched battlements.

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The Churches erected in the Eastern division of the Roman Empire appear to have been in the form of a Greek cross, on the plan; having the four arms divided into aisles by piers, ornamented with pilasters or columns, and covered by hemicylindrical or groined vaults, and the centre crowned by a large cupola or dome, supported by pendentives at the angles of the four central piers. Semicircular recesses were formed at the extremities of the arms of the cross, and covered with half-domes; sometimes small domes were placed about the principal or central one; over the intersections of the side aisles of the building, and above the aisles of the nave or of the transepts, or of both, were galleries for the accommodation of the female part of the congregation.

The Churches of Italy, which appear to have been the work of Greek artists, as those of St. Mark and St. Vitale, resemble in many points the Churches before mentioned; most of them are covered in the interior, at intervals, with mosaic-work, of which the figures are in colours on a gold ground. The ornamental foliage is long and pointed, and appears to be a corruption or modification of that on the early Greek rather than that on the Roman edifices, and the monogram of Constantine is frequently found on the walls. The arches are invariably semicircular.

aracters the Lom- d-Gothic urches.

The plan of the Lombard Churches was a Latin cross; the longer arm, in which was the principal entrance, was usually on the Western side, and at the extremity opposite the entrance was the apsis or semicircular recess. The interior of the Church is divided into one central and two or more lateral naves, by parallel ranges of columns in the direction of the length of the building. These columns support semicircular arches; and over them are the side walls of the central division, which are carried up to a considerable height above those of the body of the Church. The ceilings of the side aisles are covered by roofs sloping down towards the exterior, and that of the centre by a high-ridged roof forming a pediment or gable at each extremity. In general, these Churches have no galleries above the side aisles, and in this also they are distinguished from the Churches of the denomination last-mentioned; another distinction appears in the figure of the dome, which generally, instead of being hemispherical, is formed in faces rising from the sides of a polygon, and terminates with a pointed top. The principal decorations of the façades and side walls, on the exterior and interior, are ranges of small semicircular arches, which rise from columns or pilasters, and are either attached to the wall or stand before it so as to form galleries open towards the exterior. It must be observed that originally there were no buttresses or pinnacles about the walls, though these were subsequently added to the other features of the style.

It may naturally be inquired why such a profusion of arches should be employed on the exterior of a building merely for ornament; and, perhaps, the solution of this question may be found in the taste for open galleries, so prevalent in the ancient World, which shows itself in the peristyles and porticos of the ancient Greeks and Romans, and in the upper galleries of the Heathen Basilicæ. In the progress of improvement, a row of semicircular heads over the apertures between columns might, not unreasonably, be considered as more ornamental than a simple rectilinear entablature, which, at first, crowned those apertures; and, at least, by lessening the height of the columns themselves it would permit a smaller diameter, and thus give the arcade a light appearance. That which was employed in the interior of Churches would soon be adopted as an external feature either for convenience or ornament; and, as there is always a disposition in Man to carry every thing to excess, the arcades were soon multiplied till the whole appeared to be merely the frame of an edifice, to which buildings thus ornamented have been compared. The ornamental foliage on these buildings appears more rounded than that on the Greco-Italico Churches, and seems to have been more directly copied from the ornaments on the ancient Roman edifices.

The most ancient Churches of Italy have a lofty tower, detached from the building, but in its immediate vicinity, perhaps to distinguish the sacred edifices from other public buildings of the city; and in these were placed the bells which served to notify the times of prayer.

In addition to the Church itself it was necessary, in the early Ages of Christianity, to have a building in which the baptism of the people who were converted from Heathenism might be performed. This rite being performed by immersion, and the number of persons being considerable, because in general it took place only at the two most solemn festivals of the year, a spacious building for the purpose was required, and one was usually erected in the vicinity of the Church. The Baptisterium of Constantine is the earliest example of this species of building.

Among the ancient Romans a law existed that no one should be buried within the walls of the city; but after the establishment of Christianity, a practice arose of enclosing a piece of ground near the Church to serve as a place of public interment, and the enclosing walls were sometimes ornamented with features resembling those of the Church itself. The Campo Santo, at Pisa, which we have described, is one of those cemeteries.

The style exhibited in these Italian buildings seems to have been nearly the same as that which prevailed in the North of Europe at the same time, and the parent of that which followed it, and which flourished till the XVIth century. The latter was chiefly distinguished from it by a modified form of the arch, and an excessive enrichment of all its members.

Lombard Tombs.

In various parts of the North of Italy are some remarkable Tombs, which appearing to have been executed about the period of which we are now speaking, may not improperly be made to terminate this Chapter.

One of the most remarkable is that of Theodoric, at Ravenna; this has an octagonal basement, to the top of which are ascents by flights of steps supported on arches, and in one face are windows and a doorway, all with semicircular heads. Upon the basement appear to have stood small columns supporting semicircular arches, and forming a gallery about the body of the building like one of those in the Campanile at Pisa. The whole is crowned by a dome, 38 feet diameter, cut from one stone in the form of a segment of a sphere. The voussoirs, in the large arches of the basement, are notched in the Saracenic manner, and a Saracenic ornament surrounds the base of the dome. This work resembles the Mausoleum of Hadrian, from which, perhaps, it has been copied.

In the same, as well as other cities of that part of Italy, are small Tombs or Sarcophagi having semicircular ends, ornamented in various ways; some have the appearance of scallop shells, and others seem to be debased imitations of the ancient Greek fleurons. Such Tombs are to be seen in the Church of St. Apollinare, at Ravenna, which from its resemblance to those of the Greco-Italico style, must be of high antiquity. In the same place are others having their upper surfaces in the form of two curves, rising from the sides and meeting in a longitudinal ridge over the middle; at the extremities of the Sarcophagus the face is sunk and forms a panel with margins about it, the upper one of which has the appearance of a cuspid arch, and may have been one of the first objects from which the idea of that feature has been taken.

CHAPTER II.

Description of the principal Gothic Cathedrals on the Continent of Europe.

Few remains of Roman Architecture in the North of Europe.

Though the Architectural works of the Romans, executed in the North of Europe while they had possession of this part of the World, must have been numerous, yet it is remarkable that nothing remains of them except the pavements and other ruins which have been discovered under ground in various places; and which are insufficient to enable us to form an idea, beyond the vague one of magnificence, respecting the plan or construction of their edifices. So great has been the destruction perpetrated by the Heathen invaders of these Countries upon the monuments of Art left by the Romans, that it is believed every building was destroyed and the Art of construction so completely forgotten, that when the present Monarchies of Europe were established, the Princes were obliged to send to Italy, or to Constantinople, for artists to execute the edifices which they intended to build.

We purpose now to give a short account of the principal Churches erected in the North of Europe from the fall of the Roman power till the complete establishment of the Gothic style of Architecture; beginning with those of Germany, because there are still remaining in that Country portions of buildings which may lay claim to an antiquity superior to that of the existing buildings in any other, on this side of the Alps. Our descriptions are necessarily confined to the Ecclesiastical edifices, because these are the only buildings which have survived the lapse of Time and the destructive caprices of Man; and before we enter into any particulars respecting them, it will be necessary to exhibit the disposition of their parts, and the principal objects which serve the purposes of support and ornament; in order that the reader may be enabled to follow the description to more advantage. In pl. xviii. is given a plan of Litchfield Cathedral, which may serve to show the figure and divisions of the kind of building now to be considered.

General plan of the Northern Gothic Churches.

The Latin cross was the form of plan adopted in the Gothic Churches of Europe, except those of small dimensions, in which the plan was frequently bounded by a simple rectangle; and some of the principal Cathedrals, which had two parallel transepts, both crossing the body of the Church at right angles, and nearly dividing its length into three equal parts. The nave, and sometimes also the transept, was divided into three parts longitudinally by two parallel rows of columns; but occasionally the former was divided in a similar manner into five parts. The columns were at first simple, but afterward, they consisted of several small shafts united in one cluster, from the capitals of which sprang a longitudinal row of arches on each side of the central division of the nave or transept; these were at first semicircular, and subsequently, each consisted of two segments of circles, rising vertically from the columns, and meeting in a point at the top, over the middle of the interval between the columns. The lateral aisles were lighted by windows in the walls; and their ceilings which, in some cases, were on a level with the crowns of the arches before mentioned, were covered exteriorly by an inclined roof, on each side; vertically over the arcades of the nave were raised walls to a certain height, supporting in general a groined vaulting over the central division, and this was covered by a roof which formed two inclined planes meeting in a ridge above. At the intersection of the arms of the cross a central tower was raised upon four arches to a still greater height; this, which occupied the place of the cupola in the Southern Churches, was terminated by one tall pyramid or spire, or by a flat roof with a small pyramid or pinnacle at each angle of the tower. At first the great tower, which in the Italian Churches was at a distance from the building, was attached to the Western extremity, and was also carried considerably above the roof; afterwards, in the Cathedrals, two such towers were frequently raised, one on each side of the nave at the Western extremity, and, in this case, the principal entrance was between them.

In the Cathedrals there was commonly formed above the ceiling of the lateral aisles of the nave and transept, one, or even two tiers of galleries, with open arcades in front vertically over those below, and lighted by windows in the walls. The principal arches of these galleries were commonly divided into two or three apertures, and hence, probably, the galleries obtained the name of *triforia;* we have said that in the primitive Church they were intended for the female part of the congregation; subsequently they served for the stations of persons who came to witness the grand processions which occasionally took place in the Cathedral; and in Conventual Churches they were appropriated to the nuns who assisted at the celebration of divine service; and, thence, they had the name of *nunneries.* Above these galleries were the roofs of the lateral divisions of the Church; the walls over the arcades, which were raised still higher, were perforated by windows, and this was called the *clere* or *clair* story. The ceilings of the interior divisions of the Church were usually constituted by a groined vaulting, often of a complex nature, and ornamented with mouldings, on the ribs formed at the ridges of the groins.

The name of *nave* is generally applied to the Western part of the Church; near the centre is the *choir*, which is separated from the nave by a *screen*, and on the Eastern side of the choir is the *sanctuary*, or place of the altar. The choir, and sometimes all the Eastern part of the Church, was appropriated to the clergy; and hence it had the name of *presbytery*.

Within the side aisles of the nave were sometimes enclosures serving as oratories; and frequently, in the rentrant angles, between the body of the Church and transept, were recesses from the latter, serving as Chapels and dedicated to particular Saints. But beyond the choir, towards the East, and communicating with the nave and transepts by the lateral aisles, was frequently a building constituting a Chapel dedicated to the Virgin, and hence called *Our Lady's Chapel:* the Eastern extremity of this Chapel generally terminated the whole building on that side. This, however, was not always the situation of the Lady Chapel; for, at Canterbury, it is placed in a transept, and at Ely, it forms a distinct building. Immediately within, or in front of the Western entrance, was frequently a porch, which in the primitive Church served as a station for the penitents; subsequently, in Conventual Churches, this was called the *Galilee*, and in it the monks were allowed to see their relatives.

The oldest Churches of the North had their walls ornamented, rather than strengthened, by a sort of buttresses with plain fronts, and projecting but little from the faces of the walls, so that they resembled pilasters without bases or capitals. But in later times, at the angles of the Church, and frequently between the windows along the walls, were placed massive buttresses which, in both situations, generally rose above the tops of the walls themselves, and were terminated either in small pediment heads or in pinnacles. When the side walls over the interior arcades rose very high above the side walls of the aisles, buttresses in the form of arcs of some curve were extended from the top of the vertical buttresses, over the roofs of the aisles, to the top of the former walls; these are what were called *flying buttresses*, and they served to resist the lateral pressure of the vaults in the lofty roof.

The Western extremity of the roof terminated in a pediment or gable, the sloping sides of which, as well as the horizontal summits of the side walls of the building, were sometimes ornamented with battlements. In the Western façade of the building, and in the Northern and Southern façades of the transept, was often a great circular window; but commonly the Western front, between the towers, was occupied by one great window, with vertical sides, and a top in the form of a pointed arch. All the windows, the breadth of which was considerable, were divided into two or more apertures, or *lights*, as they were called, by vertical posts, or *mullions*, the tops of which branched off to the right and left, generally forming several intersections; and, when the height of the window was great, it was divided into two or more parts by horizontal bars, mullions, or transoms. Over the extradosses of the windows were frequently formed rectilinear or curvilinear pediments, the form of the latter coinciding sometimes entirely with that of the curved head of the window, in which case it took the name of a *label*, a *hood*, or a *weather-moulding;* but sometimes the coincidence only took place in the lower part of the head of the window, the upper part of the pediment turning off so as to form a curve of contrary flexure on each side; and these met in a point above the apex of the window.

Frequently there are formed in the walls ornamental apertures, consisting of three or more segments greater than semicircles, disposed about the circumference of a circumscribing circle, and meeting each other in cusps projecting towards the centre; these, from their resemblance to leaves, have, according to the number of the segments which compose them, the names of *trefoils*, *quatrefoils*, &c.

The intersecting ribs of the groined ceilings in the interior, and the branching mullions of the windows, form what was called *tracery-work*. Along the sloping sides of the gables of the building, of the archivolts or pediments of windows, and the ridges of spires and pinnacles, were frequently placed sculptured leaves, at intervals; these were called *crockets*, from their curling forms, and the summits of pediments and pinnacles were frequently terminated by a knot of foliage which was called a *finial*. The tombs and shrines in Churches, and the niches for statues on the exterior and interior faces of the walls, were generally covered with canopies adorned with sculpture of the most elaborate and delicate execution, which received the name of *tabernacle-work*.

Attached to the Cathedral was the Baptistery, a building expressly erected for the purpose, as was the case in Italy. Its plan was frequently polygonal, and its roof was crowned by a tall pyramid or spire rising from the tops of the walls.

On one side of the nave, generally on the South, were situated the cloisters, a quadrangle which, like the interior peristyles in ancient edifices, had its centre open to the sky; surrounding this was a gallery, with an arcade or range of windows towards the centre, and covered above by a groined vaulting either plain or ornamented. It served as a place for exercise, and communicated with the nave of the church by two entrances, for the convenience of the processions. On the exterior sides of the gallery, except on that which joined the Cathedral, were the apartments of the Ecclesiastical Officers; or, if the Church was conventual, the apartments of the monks, the Refectory, and the Common parlour. On one side of the nave was the Consistory Court, and the Chapter-house, where business was transacted; and, near this, was the Library and Treasury, where the Church plate was kept. Besides these buildings there was an Infirmary, an Almonry, and apartments for the entertainment of visitors. The whole, including the gardens, stables, and offices, was surrounded by a high wall, with battlements and towers.

The oldest Northern Churches are of the time of Charlemagne.

If we leave out the doubtful evidence afforded by some very small portions of one or two French Churches, for which a higher antiquity has been claimed, we shall find that the construction of none of the Ecclesiastical structures beyond the limits of Italy can be referred to a period earlier than the time of Charlemagne. From this time is to be dated the reestablishment of something like order in the Governments of the North of Europe; and, by the influence of the Clergy, a great portion of the wealth of the States was then directed to the building of magnificent edifices for Religious purposes. Several of these, erected during the reign of that Monarch, are said to have had great resemblance to the Churches executed in the Eastern Empire; and, like them, to have been proofs of the low state of the Arts in those days.

According to Dr. Moller, part of the Cathedral of Aix la Chapelle, and the portico of the Convent of Lorsch, near Worms, are the only buildings of the time of Charlemagne which are extant in Germany. In France, all the Churches of that period having been subsequently rebuilt, it is become impossible to determine what part, if any, of them remains in its original state.

The portico at Lorsch. The Church attached to the Convent at Lorsch was founded by Pepin, and burned down at the end of the XIth century. It was presently, however, rebuilt, and if this second Church, the ruins of which still remain, resembled the ancient one, it must have consisted of three longitudinal divisions formed by two rows of pillars supporting semicircular arches; the middle division is higher than the other two, and the windows, which are small, have semicircular heads. In front of the Church was a quadrangular peristyle or arcade, at the entrance of which is the portico above mentioned. The plan of this portico is rectangular; its length is 35½ feet and breadth 26 feet; in each of the longer sides are three open semicircular arches formed by voussoirs springing from imposts on the piers. The faces of the piers are ornamented with half-columns of an Order resembling the Composite, and having Attic bases; the height of the column, including the base and capital, is equal to 12.79 feet, and its diameter to 1.176 feet. Over these, is a horizontal band, ornamented with sculptured foliage, and supporting an upper story; in front of which are ten fluted Ionic pilasters, the capitals of every two of which are connected by the two inclining sides of a rectilinear pediment, and above this is a cornice with modillons. This upper story, and the staircases which lead to it, have, however, been erected at a later time.

Cloisters at Aschaffenburg. The Cloisters also of the Abbey Church, at Aschaffenburg, seem to have been erected about the same period. The corridor surrounding the quadranglar area is open towards the interior, and consists of square piers, between every two of which are semicircular arches springing from the half-columns attached to the piers, and resting upon columns in the intervals. These columns are 5 feet high and 6 inches in diameter, with a sort of Attic base, and a capital ornamented with foliage, the height of which is about 18 inches, from the astragal to the top of the abacus. See pl. xv.

St. Castor, at Coblentz. The Church of St. Castor, at Coblentz, part of which appears to have been built in the XIth century, is perhaps one of the latest of the German Churches which were executed with semicircular arcades in the interior; the arches on each side of the nave have this form, and spring from square piers, to each face of which a half-column is attached. A pier thus ornamented may be considered as one of the steps leading to the clustered columns, which sometime afterward became common in Europe.

Cathedral at Worms. During the XIth century, a change seems to have taken place in the style of the German Churches, both with respect to the plan and to the forms of the features, of which change the Cathedral at Worms, executed in 1016, is an example. The plan of this building has the figure of a Latin cross, and the body is divided into three parts longitudinally, by arcades springing from square piers, the faces of which are ornamented with columns. Semicircular arches are the prevailing features on the exterior, but in the interior, the arches are alternately semicircular and cuspid or pointed; the latter being formed of two segments of circles, the radii of which are nearly equal to the span or breadth of the aperture, and their centres in a horizontal line passing through the tops of the piers. This difference in the forms of the arches in the same building, seems to indicate a struggle between the ancient style and one recently invented; and if any dependence can be placed on the date of the erection of this Cathedral, or if the pointed arches have not been introduced at some subsequent period; (and the regularity of their distribution renders it probable that they form part of the original design of the building;) it must be concluded that this is one of the most ancient examples in which that species of arch occurs. Both the central and side aisles of the nave are covered by a groined vaulting. The Church has two chancels, one at the Eastern extremity beyond the transept, terminating in the interior in a semicircle, but in the exterior in a rectilinear face; the other, at the Western extremity, probably of later date than the rest of the Church, terminates in three sides of an octagon. The present entrance to the Church is by a doorway in one of the side walls of the nave.

Church Gelnhau The Churches of Germany erected during the XIth and XIIth centuries present the same mixture of semicircular and pointed arches; but subsequently to that period, the former style seems to have been superseded by the general use of arches of the pointed kind, and, occasionally, there occur apertures the heads of which are formed by the meeting of three segments of circles in the manner of trefoils.

One of the first of the German Churches executed in the new style is that of Gelnhausen, in Swabia, which is supposed to have been built in the beginning of the XIIIth century. Its form is that of a Latin cross, and beyond the transept, the Eastern end, which is flanked by two octagonal towers with plain buttresses at the angles, terminates in three sides of an octagon. In the faces on the exterior of the Eastern extremity are long narrow windows, like those in the Constantinopolitan Churches, but with cuspid heads of the lancet kind; and above them are ornamental recesses of a semicircular form. Over these is a row of small columns, attached to the wall, and supporting arches with trefoil heads; and in the wall, between the columns, are quatrefoil windows inscribed in circles: above the arcade, on each face of the octagon, is a small window divided into two apertures, each of which is terminated above by a trefoil head. Each face is crowned by a rectilinear gable, under the sloping sides of which are *nebulæ*, or semicircular ornaments like small arcades, of the kind exhibited in the Lombard Churches, but without the columns; and the whole octagon is crowned by a lofty, plain, pyramidal roof. The two flanking towers are divided into five parts horizontally by rectangular panels on each face, the upper part of the panel being ornamented with semicircular notches like those above mentioned; each face is crowned by a small pediment, and the tower is terminated by a small pyramidal spire without ornament.

The central tower of the Church is also octagonal, and contains two tiers of windows; some of those in the lower tier have double, others triple apertures, separated by vertical bars, or mullions, and each is formed with a trefoil head; those in the upper tier have double apertures with cuspid heads. The middle aperture, in each of the three light windows of the lower tier, is higher than that on each side; and the heads of all the three are inscribed in one general semicircular top. This tower is also crowned with a plain pyramidal spire. The bases and capitals of the pillars in this Church are well executed. See pl. xv.

Cathe- e, at Op- heim.

The Church of St. Catherine, at Oppenheim, is also in the form of a Latin cross, consisting of a rectangular nave and transept. The chancel at the Eastern end terminates, on the plan, in five sides of an octagon, and in the rentrant angles between the transept and chancel are recesses formed each by three sides of an octagon. Like several other Churches in Germany, there is a second chancel, at the Western extremity, which terminates also in three sides of an octagon, and the entrances are on the North and South faces of the transept. According to a manuscript Chronicle, says Dr. Moller, the nave and Eastern chancel were begun in 1262, and finished in 1317. The Western chancel was consecrated in 1439.

The whole length of the Church, including the two chancels, is 268 feet, of which 92 feet are taken up by the Western chancel, the breadth of which is 46 feet. The length of the nave is 102 feet, its breadth 86 feet, and it is divided into three parts by two rows of pillars, consisting each of several columns clustered together. The length of the transept is 102 feet from North to South, and its breadth 31 feet; and the two side aisles of this Church are occupied by small Chapels, or Oratories.

At the extremities of the nave on the Western side are two towers on square bases, each divided into four stories, and crowned by an octagonal spire; and in the three upper stories are round-headed windows, with single or double apertures separated by a pilaster. The lower windows in the sides of the nave occupy all the spaces between the buttresses; they have no mullions, and are crowned with pointed arch tops. The buttresses have no pinnacles, and their exterior faces are ornamented with panels. The upper windows are crowned by rectilinear pediments, ornamented with crockets, and there are slender pinnacles between them. The doorway in the South transept is terminated by a pointed arch, and there is one lancet-headed window above. The face of the transept is terminated above by a gable, within which are seven small pediments, and at the angles of the transept are buttresses which terminate in pinnacles. The sides of the half-octagon at the East end have lancet-headed arches between the buttresses, and the latter are without pinnacles. A large circular or rose-window is placed in the Western façade; this is one of the most beautiful of its kind, and is formed of twenty small leaves, which are grouped under five large ones. The tower over the centre of the cross is octangular; each face contains a pointed window, and is terminated by a pediment, and between the latter are pinnacles. The centre is covered by a small cupola. The clustered columns of the nave are similar to those in the Church of St. Castor, at Coblentz; they consist of four large and four small half-columns united together, and seem to have been derived from the practice of rounding the angles of a square pier, each face of which had been adorned with an attached half-column.

edral at sburg.

The Cathedral of Strasburg, which, for its high degree of enrichment, holds the first rank among the Gothic Churches of the Continent, was begun in 1277, by Erwin de Steinbach, and brought to its present state in 1439. Its plan is a Latin cross, the Eastern end terminating in a semicircle in the interior, but outwardly in a rectilinear face; and in the rentrant angles between the nave and transept are two small Chapels. The length of the body of the Church is 324 feet, of the transept is 150 feet, and the height of the vault is 98 feet; the nave is divided longitudinally into three parts by two rows of clustered columns.

The Western façade is divided into three parts, vertically, by buttresses, the faces of which are ornamented with canopies and statues; each of the three portals is crowned by a rectilinear pediment, highly ornamented, and the diverging sides of the doorways are filled with statues. The other windows of the façade are of the pointed kind, and they are divided into three or four apertures by slender pillars, which branch at top to form intersecting arches, and the whole façade is crowned by a horizontal cornice. The Cathedral, which has never been completed, has but one spire, crowning the tower at the North-West angle; this is of a pyramidal form, with pointed windows and trellis-work. Its height is 414 feet, which is greater than that of any other Church in Europe.

These examples will be sufficient to give an idea of the styles of the German Gothic Churches: we proceed next to describe some of the Churches of France which were executed within the same period.

The first Churches in France.

The earliest Churches erected in France are supposed to have been those built at Paris, by Clovis and his son Childebert, about the end of the Vth and the beginning of the VIth century: their forms were probably the same as those of the Churches of Italy, and, no doubt, of other parts of Europe at the same period; but all that the advocates for the antiquities of the French edifices can assert to be left of them—and of the assertion who can vouch for the truth?—is the Tower of St. Germain des Près, at Paris, and that of St. Peter, at Chartres. The vault of the Crypt under the Eastern end, and the principal entrance of the present Church of St. Denys, near Paris, are supposed to have been part of the works of Pepin and Charlemagne, by the latter of whom the Church was completed in the year 775.

The Church of St. Germain, which was begun by Childebert, about A. D. 557, is said to have been extremely magnificent. It was cruciform on the plan, and the roof was sustained by marble columns; the pavement was of rich mosaic, the roof externally and internally was covered with gilding, and the walls were painted on a gold ground.

The Church of St. Denys, originally built by Dagobert, resembled, it is said, that of St. Germain, both in its general form, and in the profusion of mosaic work with which it was decorated. This was taken down, and one was constructed by Pepin and Charlemagne, on a greater scale, which was subsequently destroyed by the Normans. The form and ornaments of these buildings sufficiently show that they were copied from the Basilican Churches of Rome, or from the later erected edifices of Constantinople.

Destruction of the Churches by the Normans.

The invasions of France by the Normans considerably impeded the progress of Architecture in that Country; and though several edifices seem to have been raised in those troublesome times, which continued from the VIIIth to the XIth century, yet a greater number was destroyed by the Barbarians. But in the beginning of the XIth century, two of the greatest works of France, *viz.* the Cathedral of Chartres and the Abbey of Clugny, were erected. Both of these edifices have the form of a cross on the plan; the length of the first is 420 feet, and its breadth 108 feet; on each side of the choir the aisles are double, and round the interior of the transept they are single. The Abbey Church of Clugny, which is, perhaps, the most interesting of the ancient Ecclesiastical monuments in France, was erected about the year 1056; and about the same time the Churches of St. Germain des Près and St. Genevieve, which had been destroyed by the Normans, were restored by Robert the Pious. The style of all these buildings is the same as that which generally prevailed in Europe at the same time, *viz.* the Romanesque, or as it was subsequently called, the Norman; and which is sometimes characterised as an imitation of the Lombard-Gothic.

Restoration of the Churches in the XIIth century.

But soon after this time, that is in the beginning of the XIIth century, the cuspid arch appeared in the buildings of France, mixed, as in Germany, with the round Lombard or Norman arches; and, probably, some of the earliest examples of it are contained in the Church of St. Denys and the Monastery of the Knights Templars, the building or restoration of each of which was begun about the year 1137. Towards the end of that century, the Eastern part of the Cathedral of Notre Dame, at Paris, the Choir of the Cathedral at Lyons, and the Collegiate Church of St. Nicholas, at Amiens, were also begun, though they were not finished till long afterward; and from this time the round arch and heavy pillars of the Norman style entirely gave place to the pointed arch and clustered column.

St. Germain des Près.

The Church of St. Germain des Près, after having been thrice burned by the Normans, was rebuilt by the Abbot Morard, in 1014, and part of the work executed under the direction of that Prelate is still standing; the new Refectory was begun in 1236, and the Chapel of the Virgin in 1244. The exterior of the building is not remarkable for any thing but its antiquity; the Western end is terminated by a tower which, it is pretended, is part of the edifice constructed by Childebert, and there are two other towers in the angles formed between the body of the Church and the transepts. The interior is low and mean, and lighted by small semicircular-headed windows. Those columns which have stood since the time of Morard are of an Order resembling the Corinthian, but the capitals of some of the others are composed of birds and griffins. The arches which spring from the columns in the body of the Church are semicircular, but those at the Eastern extremity are of the pointed form; either these were erected at a subsequent period, or, as Mr. Whittington supposes, they were originally made so in order that they might have the same height as the others with a smaller span.

St. Denys.

The Church at St. Denys was restored, after its destruction by the Normans, by the Abbot Suger, who was elected in 1122: and both the Western front and part of the Eastern arcade are ascribed to this Prelate; it must, however, be very doubtful what part was really executed by him, because it is impossible to ascertain what remained after the destruction caused by the fire in 1231. The oldest columns are in the Lombard style, but the pointed arch occurs in all that part of the structure which is supposed to have been executed in the time of Suger. The nave, choir, and transept were built about the middle of the XIIIth century. The spire is lofty and perforated by round-headed windows; the windows of the body of the Church are nearly 40 feet high, and are divided by four vertical mullions terminating in arches, which support three sixfoils or roses delicately sculptured. The walls are supported laterally by perforated or arched buttresses, and the portal is crowned by a semicircular arch.

Notre Dame at Paris.

The Cathedral of Notre Dame, at Paris, is said to have been begun by Childebert, in A. D. 522; but, like most of the Churches in the North of France, it was destroyed by the Normans. The present edifice was founded in 1010, and was, probably, completed about the middle of the XIVth century. The body of the Church is 466 feet long, and 180 feet wide, and of a rectangular form, except that the Eastern end terminates in a semicircle; and the building is remarkable for having no transept, from which we may, perhaps, conclude that the original plan has never been altered. The interior arrangement is extremely simple, its whole length being divided into five aisles by four rows of Lombard columns, and there are rectangular recesses along all the interior of the side walls, and of the Eastern extremity.

In the Western façade are three portals crowned by pointed arches of small elevation above the foot of the curve, and above these is a horizontal row of recesses with trefoil heads containing statues. Over these, in the centre of the façade, is a great circular window, and on each side a double window inscribed in a pointed arch, with a quatrefoil ornament over the mullion. A horizontal row of pointed arches on slender pillars adorns the top of the body of the Church; on the exterior, and over each extremity of the façade, is a tower with a flat roof. The style of the whole is heavy, and in some parts it is excessively ornamented, while other parts are much too plain.

Cathedral at Rheims and Amiens.

In the beginning of the XIIIth century the two most splendid Ecclesiastical edifices of France were erected, *viz.* the Cathedrals at Rheims and at Amiens. The first has the form of a Latin cross, on the plan, the whole length of which from East to West is 492 feet, and breadth between the Northern and Southern faces of the transept is 190 feet. The interior of the body of the Church is divided into a centre and side aisles by two rows of columns. The width of the transept, from East to West, is 98 feet, which is equal to that of the body of the Church, and this is divided into three parts by two rows of columns in a Northern and Southern direction. Beyond the transept, towards the East, are two rectangular Chapels, one on each side, and five recesses, disposed in the circumference of a semicircle, terminate the building at that extremity.

The Western façade has three entrances crowned by very lofty pointed arches, and over each is a pediment ornamented with crockets; the buttresses of the front are carried up between the pediments, and terminate in slender pinnacles, ornamented in a similar way. Between the pinnacles, and over the portal of the centre, is a grand circular window, with radiating mullions, inscribed in a pointed arch. At each extremity of the façade is a square tower, 270 feet high from the pavement, with a low pinnacle at each angle.

Mr. Whittington considers this edifice as the finest piece of Gothic Architecture in the World for its airiness and delicacy; he observes that all the heavy magnificence is below, and the lighter ornaments are towards the summit. The portal is superb, and in good proportion with the rest of the building; and the pinnacles, which are finished with figures, flowers, and crosses, are the most beautiful of their kind.

The same gentleman, speaking of the Cathedral at

Amiens, characterises it by its highly-pointed arches circumscribing equilateral triangles, and its highly-pitched vaulting only ornamented by the diagonal ribs which spring from the columns of the nave. On each side of the choir are double aisles, and in the Eastern extremity is a semicircular colonnade. In the Western front is a magnificent portal covered with sculpture representing Saints, Prophets, and Martyrs; the walls are supported by arched buttresses with ornamental perforations, and between these are two ranges of windows; each window divided by three vertical mullions, surmounted by the same number of roses, and crowned by a pediment ornamented with trefoils. In the Western front, and in each face of the transept, is a beautiful circular window.

ncient hurches in ormandy,

The old Churches of Normandy retain, at present, many features of that style which was introduced from Germany into France and England, *viz.* the semicircular arches, the short and thick pillars with rudely sculptured capitals, and the waving mouldings of the archivolts. In Cotman's *Architectural Antiquities of Normandy*, are many good specimens of the style in which those buildings were executed, and from that interesting Work we have taken the following particulars.

f Lery,

The interior of the Church of Lery, near Pont L'Arche, has a very ancient appearance, and affords evidence that this building is one of the first which was erected in the Country after the conversion of the Normans, even if it is not one of the few of an earlier date which escaped the ravages of that people. The body is divided into a centre and two side aisles; the former is covered by a hemicylindrical vault, and the side walls are supported by semicircular arches springing from columns, which appear about a diameter and a half above the ground; the capitals of these columns have little ornament, and a horizontal string extends along the nave above the crowns of the arches.

Colomby,

The Church of Colomby, near Valogne, which is of later construction, appears to be one of the first examples in which the lancet arch occurs; along the sides are nine such arches with plain buttresses between them. Over the centre is a tower with four pinnacles at the angles and an octagonal spire between them. At one extremity is the doorway with three narrow lancet-headed windows, and at the opposite end is one large window with a cuspid head.

St. ephen, Fecamp,

The circular window is found in the Church of St. Stephen, at Fecamp, but divided into four parts by three vertical mullions; it is placed in the interior of a semicircle which springs from an ornamented pier on each side. In the same Church are arcades, consisting of one large and one small arch, with semicircular heads joined together; the archivolts and jambs are ornamented with a sort of embattled fretwork, and the part where the two archivolts unite is supported by a short column.

umieges,

The Abbey Church of Jumieges is a good example of the mixture of the Norman with the later style. The outer doorway of the porch is crowned by a pointed arch with Norman mouldings, but the inner doorway has a semicircular head. In the Western front are two towers on square bases, in which are semicircular-headed doorways with voussoirs springing from pillars, and above, are two tiers of tall semicircular arches, of which the upper is supported on columns like those on the exterior of the Cathedral at Pisa, and the lower on plain piers. These towers end in pyramidal spires.

ouviers.

Lastly, in the South porch of the Church of Louviers near Rouen, are two pointed arches which meet together and form a pendent cusp in the middle. The windows in the sides have also pointed tops; the roof is hemicylindrical; and the whole Church is richly ornamented with tabernacle-work.

Churches were early built in Poland and Russia.

Christianity is supposed to have been propagated in the North-East parts of Germany, in Poland, and in Russia by Missionaries from Constantinople; and it is, probably, to the influence of some of those Ecclesiastics that we are to ascribe the erection of the Gothic Cathedrals at Tver and Novogorod; this last is said to have been built in the year 988. Churches of considerable magnitude, and of that style which superseded the Roman Architecture, must, therefore, before the end of the Xth century, have been erected from one extremity of Europe to the other.

The Northern style of Gothic Architecture introduced into Italy.

That species of Architecture which subsequently to the erection of the Cathedrals of Pisa, Orvietto, and others of the same date, prevailed in almost every Country beyond the Alps, made its way into Italy, and many Churches were constructed according to that style with certain modifications. Of these the most important is the Cathedral of Milan, which was built in 1336. This building is of white marble, and its plan is in the form of the Latin cross, the transept, however, extending but little beyond the side walls of the Church. The whole length from West to East is 490 feet, and the breadth 295 feet; and at each extremity of the Western façade is a square tower, 43 feet long in each direction. The nave, which is 279 feet long, and 197 feet wide, is divided into a central and four side aisles by four rows of columns, and is lighted by five cupolas; the transept also is divided into a central and two side aisles in the direction of its length, and the Eastern extremity of the Church is terminated by three sides of an octagon.

Cathedral of Milan.

The Western façade is crowned by a great gable or pediment, extending over the nave and side aisles; the apex is 170 feet from the pavement, and the sloping sides are ornamented with tabernacle-work. The towers at the extremities of the façade are 295 feet high, and are each divided horizontally into six parts, which gradually diminish in breadth upward, and the last forms a small pyramidal spire. The faces of the towers are covered with tabernacle-work and statues supported on corbels; and in the third story from the bottom is a window, divided into three parts by mullions, and headed by a cuspid arch. Between the towers the façade is divided into five parts vertically by buttresses, ornamented with statues on corbels, and terminating in lofty pinnacles. The central tower is similar to those on the Western façade, and about 400 feet high, and every tower and pinnacle is terminated by a statue. The roof is covered with blocks of marble so closely connected together that they appear to constitute an entire piece.

The windows and doors of the Western front do not accord with the style of the rest of the building, and have been executed at a late period; the former have semicircular heads inscribed in rectilinear architraves both horizontal and vertical, and are crowned by rectilinear or segmental pediments of which some want the horizontal cornice.

The pointed arch had been introduced into Italy before the period of the erection of this edifice, and examples of it may be seen in the Cathedrals of Orvietto and Sienna, though it did not become a general feature till that time. Many beautiful and curious specimens of the pointed Architecture occur in Italy, particularly

Architecture.

at Verona, Vicenza, and Viterbo; and we may add that the Cathedral of Florence, though erected partly under the influence of the revived Roman style, is connected, by the form of its cupola, with the Gothic edifices of the Country.

Cathedral of St. Lorenzo at Genoa.

The Cathedral of St. Lorenzo, at Genoa, presents a singular mixture of styles; on each side of the nave are Corinthian columns with pointed arches springing from them; over these is a horizontal entablature, and above the latter a semicircular arcade springing from piers and columns alternately. Both the exterior and interior of the building are fancifully adorned with alternate courses of black and white stone in stripes.

Cathedral at Palermo.

The Cathedral at Palermo is ornamented with intersecting pointed arches, and its entablature is crowned by battlements which together form a serpentine line. From the body of the Church rise four towers, in the faces of which are rows of small semicircular arches supported on columns like the ornaments of the Pisan Architecture, and the towers finish with Gothic pediments and pinnacles. In the second story of the porch of the same Cathedral there are three pointed arches supported by single columns: above the arches is a horizontal entablature and a general pediment. The walls are inlaid in the manner of the Saracenic work, and Mr. Forsyth observes that the style of the whole building resembles that of the Moorish-Gothic.

Spanish Churches.

We are but little acquainted with the Architecture of the Churches raised during the Middle Ages in Spain; but that little indicates a style which is compounded of the Saracenic and of that which prevailed in Europe after the introduction of the pointed arch. From the description given by Mr. Swinbourne, it appears that the Cathedral at Seville, which was built near the end of the XIIIth century, is 420 feet long, 273 feet broad, and 126 feet high. The choir is placed in the centre of the Church; all the rest of the building is cut up by narrow aisles, and the ornamental parts are clumsy imitations of models left by the Moors. At one angle stands the *Giralda* or belfry, a tower of brick 50 feet square, and 350 feet high, of which all the part from the ground to the height of 200 feet was built by the Moors about the year 1000, and is adorned with sculpture more simple than that which was generally executed by this people; the rest has been added since. within it is a winding staircase of easy ascent, and wide enough for two horsemen to mount abreast more than half way to the top.

Cathedral at Seville,

at Burgos,

The Cathedral of Burgos, which was built in 1221, is described as being equal to the best specimens in Europe of the kind called Gothic, and as having some resemblance to York Minster. At the Western or principal front are two steeples ending in spires; on the centre of the edifice is a large, square tower adorned with eight pinnacles, and on the Eastern end is an octagonal building crowned by a pyramid. The arches and foliage are executed in the most elaborate and finished manner.

at Batalha, in Portugal.

A splendid example of the Gothic style exists in the Church at Batalha, in Portugal, which was erected, in 1388, under the direction of a native of Ireland. According to the description of the edifice, given by Mr. Murphy, its plan resembles a Latin cross, and the transept is near the Eastern end; the interior is divided by columns into a nave and two side aisles, and the Eastern end terminates in three sides of an octagon. The nave and aisles are equally high, the vaults of both are groined, and the ribs spring from clustering pillars. There are two tiers of windows in the side walls with cuspid heads; those of the lower tier have their radii of curvature equal to two-thirds of the span, and those of the upper tier have them equal to three-fourths. The windows are splayed towards the interior, and the sides are adorned with many small columns, from which, stems proceed and meet at the top of the aperture; each window is divided into three parts by upright mullions; each part ends in a trefoil head; and between the tops of these and the intrados of the arch are six quatrefoils. The windows of the chancel are long and narrow, and terminate in lancet heads. The walls of the body of the Church are crowned by battlements of open-work with pinnacles. The tower is of an octagonal form, and above it is a small spire ornamented with open-work. This building may be considered, says Dr. Milner, as a pleasing variety of the Gothic Architecture, but it is not to be put in competition with many of the contemporary buildings in other parts of Europe, on the general principles of sublimity and beauty.

Having brought the Ecclesiastical Architecture of the Continent down to the time when the pointed style was generally prevalent, we proceed to describe that of England during the same period.

CHAPTER III.

Principal Gothic Edifices in Britain.

Ancient Churches at Canterbury,

As early as the beginning of the IIId century of the Christian Era, a Church is said to have been built at Canterbury by Lucius the first Christian King in Britain; and we have the authority of Bede for saying that when St. Augustine established himself in that city, about the year 600, the Church was dedicated to Christ. In the XXXIIId Chapter of his *Ecclesiastical History*, we are informed that, near the city, King Ethelbert built a Monastery and Church, which he dedicated to St. Peter and St. Paul, and in which the Kings and Bishops of Kent were to be interred.

The latter Church was, probably, built of timber, and it is by some supposed to have been divided longitudinally into three parts lying East and West; for according to Bede's History, (book ii. ch. iii.) St. Augustine and some of the succeeding Bishops are said to have been buried in the Northern portico, which has been supposed to mean the Northern aisle, and two Bishops are stated to have been buried in the body of the Church, because the portico or aisle would contain no more bodies. But Mr. Wilkins, in the *Archæologia*, (vol. xiii. p. 290,) is of opinion that the *porticus* mentioned by Bede, instead of being an aisle, was a portion of the body of the Church cut off at the Western extremity, as has been done in the Church at Melbourne, in Dorsetshire; and he thinks it likely that the British Churches of that Age, were not divided by pillars or arcades. There is nothing, however, to disprove the fact of such a division, and we find that both pillars and arches are mentioned in descriptions of the Anglo-Saxon Churches, by writers of the VIIIth and following centuries.

at York,

About the same period Churches were erected in the Northern parts of the Anglo-Saxon dominions; for, in 627, Edwin, King of Northumberland, was baptized at York, by Paulinus, in a temporary building of timber;

and immediately afterwards a Basilica of stone was erected in the same place. In the following year Paulinus visited Lincoln, where he converted Blecca, the Præfect, and his household, and built a large Church of stone, the walls of which were standing in the time of Bede. (book ii. ch. xiv.—xvi.)

Were- uth,

According to the same venerable writer, Benedict, a noble Saxon, built, in 676, a Church at Weremouth in honour of St. Peter; it is added that he sent to Gaul for artificers who might build it according to the Roman manner, by which is probably meant the style of the Lower Empire. So much expedition was used, that within a year from the time of laying the foundations the roof was put on. And, as the work drew near a conclusion, he sent again to Gaul for artificers to make glass for the windows, the Art being then unknown to the Britons.

Abben- ,

The ancient Church of Abbendon is said, in the *Monast. Ang.*, to have been built at the same time; it is described as a building 120 feet long, with circular recesses both at the Eastern and Western ends.

Scotland.

In the beginning of the VIIIth century, that which was then called the Roman style of building extended into Scotland; for, in 710, Naiton, King of the Picts, sent ambassadors to Ceolfrid, Abbot of Gyrvi, near the mouth of the Tyne, requesting him to send Architects who might build him a Church of stone in that manner; which request, according to Bede, (book v. ch. xxi.) was immediately granted. At an earlier period than this, a stone Church appears to have been erected near Wigton, in Scotland, by Bishop Ninias; this is said by Bede (book iii. ch. iv.) to have been executed in 432, and he observes that the Britons were before that time unaccustomed to building with stone. Perhaps, therefore, stone Churches existed in North Britain before the VIIIth century, but they may have been executed only on a small scale.

thedral at xham.

The Cathedral of Hexham, in Northumberland, was founded by Wilfrid, Bishop of York, about the end of the VIIth century; and its construction is particularly described in the *Tractatus de Statu et Episcopis Hagustaldensis Ecclesiæ*, by Richard, the Prior of the Cathedral, who lived in 1180, and in whose time it existed entire. He says it was furnished with a round tower, perhaps a square tower covered by a cupola; from this, four aisles, or the four arms of a cross, proceeded, and it had deep crypts and oratories with passages under ground. The walls were of great length and height, and were divided into three tiers supported by well-polished columns both square and circular, which, as well as the walls and the arch of the Sanctuary, were of stone, decorated with images in relief and painted of various colours. The body of the Church was surrounded by porticos or aisles, and Chapels of exquisite workmanship, which were divided above and below by partition-walls and winding stairs. Within the staircases and above them were made flights of steps; with galleries and passages leading from them, both for ascending and descending; and so disposed that persons might be there and pass round the Church without being seen by any one in the nave below.

It is probable, as Dr. Milner observes, that the Cathedral of Hexham had some resemblance to that of Sancta Sophia, at Constantinople, which was built about the same time; and it is also probable that the principal Churches of the Continent in that Age were designed and executed nearly in a similar manner; but the Saxon Church at Hexham may have been superior to any of the foreign buildings, for Eddius observes, that no Church equal to it in magnificence was to be met with on this side of the Alps. The same Wilfrid founded a Monastery at Hexham, about 674.

York Cathedral rebuilt.

We are brought next to the rebuilding of York Cathedral in 767. This edifice must have been magnificent for that time, though we have few particulars from which we can obtain an idea of its style; all we know of it is from the Poem of Alcuin, one of the Architects, in which it is described as having all the requisites of a complete edifice, such as pillars, arches, vaulted roofs, porticos, galleries, and altars; but these circumstances are sufficient indications that Architecture must have been cultivated and brought to a considerable degree of perfection in England at that time, which was before the invasions of the Danes occurred. Amidst the troubles produced by those invasions, it was not to be expected that the Arts should receive encouragement, still less that of building; in fact, the fairest edifices which then adorned the Country fell a prey to the ravages of those Barbarians, and the art of construction was lost. But when Alfred came to the Throne a revival took place; this Prince is said to have erected several Ecclesiastical as well as Military edifices, and even to have introduced into the former an improved style. Mr. Bentham supposes that towers and steeples were added to the English Churches in his time, *viz.* about the year 900; however, as no steeples at present exist, of an earlier date than the beginning of the XIIIth century, this circumstance is doubtful.

Ramsay Abbey.

The Abbey, at Ramsay, in Huntingdonshire, was rebuilt in 974; and, in the *Hist. Ramesiensis*, it is described as having two towers raised above the roof; one was at the Western end and the other was supported by four pillars in the middle of the building, which there divided into four parts, connected together by arches, and these extended to other adjoining arches to prevent the former from giving way. This shows, as Mr. Bentham observes, that the plan of the building must have consisted of two rectangles, crossing one another, with side aisles; but the same gentleman's opinion, that this mode of building had not then been long in use, does not appear so well founded, for the description of the Cathedral at Hexham seems to show that this building had also, on the plan, the figure of a cross, and that it was furnished with a tower.

Oxford Cathedral.

It is supposed by some that the Cathedral of Oxford was built in the reign of Ethelred, about the year 1000, but so uncertain are the dates of the early edifices of our own Country, that others place its erection about a century later; Mr. Dallaway thinks it was built in 1112. The only part of the ancient structure which remains, *viz.* the nave of St. Frideswide, is built exactly in the manner of that corrupt Roman style which characterises the oldest remains of edifices in Germany and France, and it has been considered as the best specimen of what is called the Saxon Architecture in England. To one or the other of these periods may, perhaps, be referred the construction of parts of the Cathedrals at St. Alban's and Durham.

Restoration of English Churches about the time of the Conquest.

The long and severe struggle against the Danes, joined, perhaps, to a certain dissoluteness of manner which at that time prevailed among the Anglo-Saxons, is supposed to have been the cause that the Religious edifices of the Country had very much gone to ruin before Edward the Confessor came to the Throne; this

Prince had been educated in Normandy, and, probably, the contrast between the Ecclesiastical structures of that Country and those of England struck him forcibly, and induced him to excite his people to repair their Churches and erect new ones with embellishments similar to those of the Norman edifices. After the Conquest, in 1066, the style of the Norman buildings became very general in England. The most early examples of this style do not remain at the present time in a perfect state, but enough can be seen of their ruins to show its characters. Edward the Confessor built the original Abbey Church, at Westminster; and about the same time was executed the Cathedral of Gloucester, of which a part still remains; and these seem to have served as models for the Ecclesiastical structures subsequently erected. The transept of Winchester Cathedral was erected in 1080, and the tower of Exeter Cathedral in 1112. To these may be added the lower part of St. Peter's in the East, at Oxford, and the Church of St. Sepulchre, at Cambridge; this last was erected in 1130, by the Knights Templars, in imitation of the Church of the Holy Sepulchre, at Jerusalem. It is a circular building, having internally a peristyle of eight heavy pillars, and it served as the archetype of the Temple Church, in London. Many of the Churches belonging to the greater Abbeys were erected at this Era with equal magnificence; but very few of them remain, and those are in ruins.

Cathedral at Durham.

The Cathedral at Durham must be considered as an excellent specimen of the Norman Architecture. It was begun in the time of William Rufus, about 1093, by William de Carilepho, and was, perhaps, finished by the successor of that Prelate. Originally, says Mr. Carter, the side aisles both of the nave and choir were covered with groined work formed by hemicylindrical vaults, and the ribs of the groins were embellished with carving; but both the nave and choir were only covered by the timber-roof. Various additions, however, have since been made, the first of which was the Galilee, or porch before the Western façade, by the Bishop Hugh Pudsey, between 1153 and 1195; this is a low building, with four semicircular-headed windows on each side springing from clustered columns. The plan of the whole Cathedral is rectangular, with two transepts, and it has not the semicircular apsis which was usually formed at the Eastern end of the ancient Churches. The length from the Eastern to the Western façade is 420 feet, and its breadth from the Northern to the Southern face of the Western transept, which is the longest, is 180 feet. The nave is 200 feet long and 100 feet wide; this is divided into three parts by two rows of columns, alternately round and clustering, at 15 feet from the wall on each side. The Western transept is 70 feet wide from East to West, and is divided into two parts, in a Northern and Southern direction, by a row of clustered columns at 15 feet from the Eastern wall.

Four great clustered pillars, each 50 feet high, at the intersection of the nave and Western transept, are connected above by semicircular arches, the crowns of which are on a level with the vault of the nave, and support the great central tower, which is 210 feet high, and the date of the construction of which is not ascertained. The choir is 110 feet long, and is divided into three parts like the nave; beyond the choir is the Eastern transept, which is 144 feet long from North to South, and 40 feet wide from East to West, and this forms the Eastern extremity of the Cathedral.

The centre of the Western façade is crowned by a plain gable; over the entrance is a large window of the cuspid form, divided by six mullions, and having the upper part filled with tracery. This window was formed in 1350; above it is a row of semicircular-headed niches between columns, and in the gable are five lancet-headed arches, whose heights are regulated by the inclining sides of the gable. On each side of this central division of the façade is a square tower, the height of which from the pavement is 140 feet; its face is ornamented with eight tiers of arches resting on small pillars, all with semicircular heads, except those in two of the tiers, and it has a flat roof with battlements. A short curtain, containing four tiers of semicircular-headed arches, in the Pisan style, connects each of these towers with a smaller one, which forms the extremity of the façade; the lower part of this tower is a square, and without ornament; the part above is octagonal, and contains four tiers of semicircular-headed arches; and the tower is crowned by a small pyramid.

Of the three round columns on each side of the nave the diameters are 7½ feet, and the heights, including those of the plinth and capital, are 27 feet; consequently, equal to 3.6 diameters; and the heights of the plinth and capital are each equal to about half a diameter. The plinth is rectangular and quite plain; the abacus is octangular, the curved circumference of the capital below it is divided into eight faces, as if cut by so many planes a little obliquely to the vertical, and a small fillet separates this part from the shaft. One of the three columns is fluted vertically, another is ornamented with zig-zag channels, the general directions of which are horizontal, and the third is channelled obliquely round the column to the right and left, forming a sort of network. The other columns consist of several small ones clustered together, and, perhaps, are of later date.

From the capitals of the round, and from some of the stems of the clustered columns, spring the semicircular arches which extend along each side of the central division of the nave; the other stems of the clustered columns are carried up to the height of 50 feet from the pavement. From the capitals of these, and from angels' heads attached to the walls, immediately over the round columns, and serving as corbels, spring the ribs which ornament the groined vaulting of the nave. The archivolts of the lower arcade of the nave are ornamented with zig-zag mouldings, and on the extrados is a sort of battlement. A horizontal string extends along the nave over the lower arcade; and above this is a tier of semicircular arches equal in span to those below, forming the front of the triforia; the archivolts of these are highly ornamented with zig-zag mouldings, and rest upon small pillars which are placed vertically over those in the lower tier; within each of these arches are two smaller ones, also semicircular, springing from the same imposts, having plain archivolts resting upon small pillars. Above the triforia is a tier of narrow pointed arches within the lateral vaults of the groined ceiling. The roof of the nave is formed by the intersection of ridged vaults, and, except the ribs of the groins, the surface of the vaulting is plain. This part of the building is said to have been finished in 1290.

The arcades of the choir are similar to those of the nave, but the two round columns on each side are channelled with spiral grooves all directed one way, and the ribs of the groined vaulting are more ornamented. The doorways leading from the cloisters to the Cathedral are covered with the utmost profusion of ornament. The ec-

altar-screen and episcopal throne are highly decorated with flying buttresses, niches, and pinnacles, producing a singularly rich and magnificent effect; but it must be remembered that these were executed long after the rest of the fabric. A longitudinal section of part of the nave, and an elevation of one of the doorways in this Cathedral, are given in pl. xvii.

ral at
bury.

The Cathedral Church, at Canterbury, after frequent demolitions by fire, was wholly or partly rebuilt by Lanfranc, in 1085, and enlarged to its present size about the beginning of the XIIth century. The whole length of the building, from West to East, is 514 feet; the nave is 178 feet long and 71 feet broad, and is divided into a centre and two aisles by two rows of clustered columns at the distance of 13 feet from the side walls. At the extremity of the nave is the first or Western transept, the length of which, from North to South, is 124 feet, and breadth 34 feet. Beyond this is the choir, extending from West to East 151 feet, and in breadth 38 feet; on each side of this is an aisle 16 feet broad, and separated from the choir by a row of plain circular and polygonal columns intermixed. The choir is intersected by the Eastern transept, which is 154 feet long from North to South, and 29 feet wide. Beyond the choir is the Trinity Chapel, 104 feet long from West to East, 63 feet wide, and of a semicircular form towards the East; in the interior of this Chapel is an aisle separated from the central part by a curvilinear range of plain columns in couples, at a certain distance from the walls. And, finally, a circular tower, 32 feet diameter, called Becket's Crown, opening into the Trinity Chapel, constitutes the Eastern extremity of the whole building.

At each extremity of the Western façade is a square tower, of which that on the Northern side is 100 feet high, and the other 130 feet; the former was, probably, part of Lanfranc's original structure, but the latter was built about the year 1450. And over the centre of the Western transept is another tower, 235 feet high, which was erected about the year 1500. The two former towers are strengthened on each side of the angles by immense solid buttresses reaching to the top and diminishing upwards, in projection, by steps at intervals; and the tower at the South-Western extremity is crowned by open battlements with an octagonal pinnacle at each angle. The angles of the central tower are strengthened by slender buttresses of equal thickness from top to bottom, and are crowned by pinnacles. On each face of this tower are four large windows in two tiers, of which those in the lower tier have curved pediments of contrary flexure, ornamented with crockets and finials. The exterior of the side walls of the Church are also strengthened by solid, plain buttresses terminating in ornamented pinnacles, and between the buttresses are large cuspid windows subdivided by vertical and horizontal mullions.

The vaults of the nave and aisles are groined and ornamented with tracery; but those of the choir and its aisles are more simple. The capitals of the pillars in the choir and Trinity Chapel have some resemblance to those of the Corinthian Order, and consist of two rows of leaves; from these capitals spring pointed arches, over which are triforia, or galleries, with pairs of arches in front resting on columns; some of these latter arches are semicircular, but the generality of them are pointed, and every two are inscribed within the mouldings of a third which embraces both. The archivolts of the aisles of the choir are ornamented with zig-zag mouldings.

According to the Monk Gervase, the old Church, before the fire which, in 1174, destroyed the choir, was covered with a flat painted ceiling, and there was only one triforium round the choir; the same Chronicler adds that the pillars of the new choir were of the same form and thickness as those of the old choir, but 12 feet longer; (probably their height was then doubled, for they are now about 24 feet long;) that the old capitals were plain, whereas the new ones were delicately carved; and that the vaults of the side aisles were formerly hemicylindrical, but subsequently formed with a ridge at the vertex. The present state of the Eastern end of the Cathedral corresponds nearly with the account given by Gervase, in 1180. He says, "There are large well-proportioned columns crowned with elegant capitals. Upon the abacus rest the bases of slender marble columns which mix their heads with those of other marble columns supporting the arches of the principal triforium, and from their united capitals branch out triple clusters which, at a proper height, form themselves into ribs to sustain the groining." The arches constituting these ribs are formed with an acute angle at the vertex, and those in the upper tier are alternately cuspid and semicircular, but the lower extremities of the latter are rectilinear and vertical up to a certain height above the capitals of the columns from whence they rise.

The present choir was built by two Architects of the name of William; one of these was a Norman, or Italian, the other an Englishman, and the latter is described by Gervase, as *parvus quidem corpore, sed in diversis operibus subtilis valdè et probus.* He is the first English Architect of whom we have any positive account.

The interior of the nave presents an unbroken simplicity, and exhibits the style of the XIVth century without embellishments. Above the lower arcade is a course of oblong panels, instead of the triforium, which is invariably found in all other great Churches of the same Age; and above these is a tier of windows, the form of which corresponds with that of the transverse vaults of the groined ceiling.

The crypt, or substructure, is situated under the choir and all the Eastern part of the building; and, from the ornaments found in the capitals of its pillars, its construction has been referred to the IXth century. In the Trinity Chapel, the angles formed at the vertices of the Gothic arches, by their curved sides, are of different degrees of magnitude; a variety which has evidently been caused by the differences existing in the intercolumniations, the vertices of the arches being all in one horizontal plane.

On the exterior of the building, at the Eastern end, are various kinds of arches, serving as ornaments; some are plain semicircles; others are semicircles, or cusps, intersecting each other; some, again, are of the lancet shape, and others form broad windows, the apertures of which are divided by mullions.

On the Northern side of the nave are the cloisters, a square enclosure 134 feet long in each direction, with groined vaults and arcades of pointed arches surrounding the central area. Between the cloisters and the choir of the Cathedral is the Chapter-house, a rectangular building, 92 feet long and 37 feet broad; and near this are the Treasury, Audit-room, Library, and Baptistery.

Iffley
Church.

We are induced to mention in this place a Church supposed to have been built before the death of Henry II., at Iffley, in Oxfordshire, because it resembles, in some respects, the Churches built about the same period in

Normandy, and because it may be considered as a good specimen of the Parish Churches of England, near the time of the Conquest. (Britton's *Architectural Antiquities*, vol. v.) It is of a rectangular form, 112 feet long and 30 feet wide on the exterior, and has no transept. In the Western front is a semicircular-headed doorway surrounded by zig-zag ornaments and two courses of serpents' heads; and on the exterior of these, a semicircular course of voussoirs sculptured with figures of birds, beasts, angels, and men: over the door there has formerly been a circular window, and, above it, is the gable end of the roof, in which were formerly three semicircular-headed windows, having the archivolts and jambs richly ornamented with three courses of zig-zags. The extrados of the arched tops is ornamented with a course of serpents' heads, similar to those about the doorway, and this member rests at each extremity on a twisted column, in the capital of which are sculptured centaurs, griffins, and the like.

Over the centre is a square tower, having on each face two semicircular-headed windows, the archivolts of which rest on columns.

The faces of the Northern, Southern, and Western walls have at the top and on each side a broad, plain margin projecting a little before them. The inferior edges of the horizonal margins are ornamented with a row of dentels, so that those margins have the appearance of inverted battlements; and about the windows in the tower are similar margins ornamented in the same manner. This practice of recessing the faces of the walls within margins is met with in the Churches of Normandy, and from them it was, no doubt, copied. In Churches of later date, small semicircular notches, or *nebulæ*, are cut in place of the rectangular intervals of the dentels.

Salisbury Cathedral.

The present Cathedral at Salisbury presents the most complete specimen of that kind of Gothic Architecture which immediately followed the introduction of the pointed arch; and, contrary to that which took place in the other Cathedrals of England, (which were erected in parts, at long intervals of time, and some of which are unfinished even at the present day,) this, which was begun in 1220, was completed, if we except the spire, a work of much later date, in about 40 years; so that it is almost without any mixture of the succeeding styles. The plan is in the form of a double cross; the length of the nave is 276 feet, of the choir 140 feet, and of Our Lady's Chapel, at the Eastern extremity, 65 feet; the general breadth is 76 feet, and the height, from the pavement to the top of the vault of the nave, is 84 feet. The length of the principal transept is 210 feet and its breadth 60 feet. The cloisters adjoining it are 160 feet square, and there is an octagonal Chapter-house. The outside walls of the aisles are supported by solid buttresses, and flying buttresses extend from the tops of these to the springing of the vault of the nave. The central tower is 220 feet high, of a square form on the plan, and crowned by a spire, the apex of which is 180 feet above the top of the tower, so that the whole height of the building and spire is 400 feet. The spire itself is 2 feet thick at bottom, and diminishes gradually to 7 inches at the top.

The columns of the nave are 28 feet high, and each consists of one stout cylinder in the centre, with four smaller ones attached to it; two of these are at the extremities of that diameter of the central column which is parallel to the direction of the building, and the other two are at the extremities of a diameter at right angles to this; by which means, as is observed by Mr. Knight, the greatest possible space is allowed for communication and for the passage of light from the side windows. The five columns, thus forming one cluster, have a common base and capital, and from the capitals spring the pointed arches, the radii of the sides of which are equal to three-quarters of the spans or intervals between the columns supporting them; and the sides themselves seem composed of a number of curved reed-mouldings clustered together. Above the arcade of the nave is a small horizontal cornice proceeding through the length of the building, and making a finish for the lower story. Over each side aisle is a suite of low galleries or triforia open towards the nave, but having no windows towards the exterior. A vertical stem rises from the capital of each of the opposite pillars of the nave, crosses the horizontal cornice, and proceeds without interruption to the groined work in the top of the roof. The windows in the walls of the building are lancet-headed; those of the lower tier are placed two together between the buttresses, but those in the clere-story, or upper part of the walls of the nave, are divided into three apertures by columns or mullions.

In the Lady Chapel the central stems of the clustered pillars resemble Roman columns, except that they have no diminution; they have Attic bases coarsely cut, and the capitals are similar to those of the ancient antæ pilasters; the other stems in each cluster are detached from that of the centre, and have distinct bases and capitals. The Western end of the Cathedral is covered with niches and rows of statues; and this is, probably, the earliest example of that practice in England.

In the screens which separate the Northern and Southern ends of the smaller transept from the nave, is a pointed arch springing from the clustered pillars on each side, and rising as high as the tops of the other side arches; and, above this, is an inverted arch descending from the foot of the ribs of the vault at the top of the triforium, on each side, and having its lowest point coincident with the crown of the arch before mentioned; this feature occurs in the Cathedral at Wells, and in several other Cathedrals of this Country.

The Southern face of the transept contains, in the gable, a circular, or, as it is called, a Catharine-wheel window; and below it is a row of narrow windows of the lancet form. The central tower has two windows in each face ornamented with curved pediments and crockets, and it is crowned by battlements, but is without pinnacles. In the gable of the Northern transept is a row of pointed arches placed on small attached columns as ornaments against the face of the wall; and the heights of the arches decrease from the middle one outwards, in order to suit the inclining sides of the roof.

In this Cathedral are some ornaments which resemble those of the Norman Architecture; many of the interior arches are sculptured with a zig-zag, and the same moulding appears round the arches and windows of the West front.

The Baptistery is an octangular building on the Northern side of the Church, with broad and cusp-headed windows, having three circular ornaments within the arch; there are buttresses at the angles terminating in pinnacles; and the whole building is covered with a high pyramidal roof.

York Cathedral.

The Cathedral at York is remarkable for the simplicity of its plan, which is in the form of a Latin cross, the arms of which are all rectangular, and the transept is in the middle of the length of the building. The whole length is 465 feet from East to West, and its breadth from the Northern to the Southern face of the transept is 222 feet; the breadth of the nave is 103 feet, and of the transept 94 feet; and the body of the Church and the transept are divided into a centre and aisles by clustered columns, 20 feet and 18 feet from the walls, respectively. In the intersection of the arms of the cross are four large clustered columns supporting the central tower, which is 182 feet high; and between the two Eastern columns is the screen separating the transept from the choir; the latter is 150 feet long, and beyond it all the Eastern part of the building is occupied by the Chapel of the Virgin. A perspective view of this building from the North-West is given in pl. xvi.

This edifice, like the generality of our Cathedrals, has been executed at different times. The most ancient part is the crypt under the choir, and this is supposed to have been built with the Norman Church in 1171; it consists of a groined work supported on four walls and on six insulated columns, each 5 feet 6 inches high and 1 foot 5 inches diameter, and some of the arches composing it are ornamented with the Norman zig-zag. The capitals, which are octangular, are sculptured, and the bases resemble the Attic kind, except in one instance, where a reversed capital is substituted for a base; from which there is reason to conclude that some part of the crypt has been formed of materials belonging to a more ancient edifice. The Southern wing of the transept was raised between 1216 and 1255, and the Northern wing was begun in 1260; the construction of the Western parts of the fabric probably extended from the beginning of the XIVth to the middle of the XVth century.

The arches of the nave are pointed, and the curved sides are cut in reed-mouldings; above their vertices is a horizontal string extending along the building, and over it comes the upper tier of windows. There are no galleries over the aisles of the nave. The arcades of the transept are sculptured with a double zig-zag, or dog's-tooth ornament on the mouldings, and the clustered columns have small capitals sculptured to represent foliage. Above these arcades are two tiers of triforia, or open galleries. The groined roof of the building is adorned with intersecting ribs of tracery-work, executed in modern times, but, probably, in imitation of the ancient forms.

At the extremities of the Western façade are two square towers with buttresses on each side of the angles, ornamented with trefoil and cinquefoil-headed arches, over which are pediments. The doorways and windows have cusp heads with reed-mouldings; the part of the windows within the arch is either pierced by three open quatrefoils, or is occupied by the branching mullions, and the extrados is crowned with rectilinear or curved pediments, which are ornamented with crockets and finials. The walls of the towers terminate in a range of battlements, and over each angle is a crocketed pinnacle. The side walls of the aisles are supported by plain buttresses terminating in pinnacles, and the walls over the arcades of the nave are strengthened by buttresses more slender than the former. A horizontal line of battlements is placed along the top of the façade and of the side walls of the building; and the inclining sides of the gable are ornamented in the same manner. The great Western window is divided into eight parts by vertical mullions; the arched sides of the head form an acute angle with each other, and the part within the intrados is enriched with open-work in the forms of leaves. See pl. xix. fig. 2.

Lincoln Cathedral.

The original Cathedral, at Lincoln, was built in 1092, by Remigius, the first Bishop appointed to an English See by William the Conqueror, but of this building nothing remains except part of the Western front and towers. The front seems to have been divided into five recesses covered by semicircular arches; over these there seems to have been a tier of small columns bearing intersecting arches, and the façade was terminated above by three gables. The original towers at the Western front were ornamented with three tiers of semicircular arches on each face; these still exist, but, at a later period, the towers were increased to their present height. The building having been injured by an earthquake in 1185, it was subsequently rebuilt, and the work was carried on at various times till the close of the XIVth century.

The plan of this Cathedral is a double cross, like that of Canterbury, but the Eastern as well as the Western front is rectilinear. The whole length is 470 feet from East to West, and the length of the Western, or greatest, transept from North to South is 220 feet. The length of the nave is 240 feet, its breadth 80 feet; and this part of the Church is divided longitudinally into a centre and aisles by two rows of clustered pillars at 15 feet from the walls. The breadth of the Western transept is 63 feet; this is divided into two parts by a row of columns at 23 feet from the Eastern wall, and the space between the columns and that wall is occupied by six chantries founded by different persons. The central tower stands over four large clustered columns in the middle of the Western part of this transept; the screen of the choir is between the two Eastern columns, and the whole length of the choir from this to the altar-screen is 140 feet; on each side of the choir is an aisle 18 feet wide; and beyond the altar-screen is the Presbytery occupying all the rest of the Church. The Eastern transept crosses the body of the Church between the choir and the altar; and it is 22 feet wide, exclusive of four semicircular recesses or Chapels, which occupy all its Eastern side.

The Western front extends North and South beyond the side walls of the building, and is terminated by two octagonal towers which are crowned by small spires. In the centre of the façade are three recesses, of which the middle one is headed by a pointed arch, the vertex of which is above 80 feet from the ground; the two others belonged to the original structure, and are covered by semicircular arches. In each of the three is a portal covered by a flat, elliptical arch with Norman ornaments, and, above them, is a large pointed window of more recent construction. The whole façade, including the flanking towers, is ornamented with tiers of lancet-headed arches on slender pillars, and a horizontal entablature crowns the whole; the execution of these ornaments is referred to the early part of the XIIIth century.

The lower parts of the Western towers are in the Norman style, and are ornamented in the following manner. In that part of each which is above the walls of the Church, are three tiers of recesses with semicircular heads resting on small columns; below these, on the Northern front, is a gable, in which are also three tiers of small semicircular-headed recesses with small columns in the Pisan style, and in two of the tiers the arches intersect each other. Similar courses of ornamental arches are placed in the gable of the Western extremity of the Cathedral, and the upper part of the gable is covered with trellis-work. The upper parts of the Western towers are of the XVth century; in each of the faces are two windows ornamented with crockets, and there is a pinnacle at each angle. The central tower is similar to these, but more enriched; its height is 262 feet.

Above the vaulting of the nave, and within that part of the roof which is between the Western towers, is a stone arch, the chord or span of which is 28 feet, and its versed sine, or rise, but 16 inches: the voussoirs are about 20 inches long, and without any appearance of being tenonted together; this arch is remarkable for being the most slender in the world, in proportion to its span.

The side walls of the aisles are strengthened by buttresses with ornamented pediment heads, and arched buttresses extend over the roof of the aisles from the upper parts of these to the upper parts of the side walls of the nave. The Eastern side of the Western transept is supported by plain buttresses, with flying buttresses over the aisle; and, in this transept, the windows are of the lancet form. In the Northern and Southern faces of the same transept are large circular windows filled with looped tracery. The whole building is covered by a lofty roof forming a ridge over each arm of the double cross.

The pillars of the nave have capitals sculptured with foliage, from which spring the pointed arches; and these consist of arcs of circles, of about seventy-five degrees each, the extrados moulding of which rests upon a head projecting from the wall, above the capital of the pillar. A slender pillar resting upon an ornamented corbel in the wall, above the capital, is carried up to the springing of the ribs which adorn the vault in the nave. A horizontal string proceeds, longitudinally, through the nave, above the crowns of the lower arches, and over this is the arcade of the triforium, or gallery, above the aisle; this consists of lancet-headed arches, in triplicate, resting on small pillars, and crowned by one obtusely-pointed arch embracing every three. Above these is another horizontal string; and, lastly, over this, and within the lateral vaults of the groins, are the clerestory windows, consisting of triple lancet-headed apertures. The dog's-tooth ornament occurs along the mouldings of these arches, and in those of the transept. A longitudinal section of the nave of this Cathedral is given in pl. xviii.

The four great clusters supporting the central tower are each composed of twenty-four attached columns of various diameters; the arches they sustain have a great appearance of lightness from the delicacy of their mouldings, and from their spandrils being decorated with trellis-work.

The Temple Church. The Temple Church, in London, may be mentioned in this place, because it is, probably, one of the first edifices, in England, in which the pointed arch was introduced. It consists of two parts; *viz.* a rectangular nave 82 feet long, and 58 feet wide, and a circular building 58 feet diameter, at the Western end of the former: this is supposed to have been erected by the Knights Templars in 1185, and the rectangular part may have been added in 1240, when the Church is said to have been rebuilt.

Within the circular building are disposed six clustered columns, at intervals upon the circumference of a circle concentric with the walls of the building, and 29 feet diameter; the tops of these are connected by pointed arches of contrary flexure, over which is raised a cylindrical tower 44 feet from the pavement, with semicircular-headed windows. The circular aisle on the exterior of the columns is covered by an equilateral groined vault, and in the walls are single lancet-headed windows. The foot of the circular wall, in the interior, is ornamented with a continuous row of lancet-headed arches on short columns, and the interior of the tower, above the roof of the aisles, is ornamented with a similar row of intersecting semicircular arches.

The walls of the rectangular building are strengthened by plain buttresses, and the whole interval between them is occupied by a triple lancet-headed window, of which the central aperture is much higher than the others, and all three are circumscribed within a broad pointed arch. The interior is divided into a central and two side aisles, all of equal height; *viz.* 37 feet, by two rows of clustered columns supporting equilateral pointed arches; the vaulting is groined, and the three divisions are covered by separate roofs.

Westminster Abbey. A small Church is said, chiefly on the authority of the Monk Sulcardus, to have been built on the site of the present Abbey of Westminster, about the year 604, by Sebert, King of the West Saxons. It was reconstructed on a more magnificent scale by Edward the Confessor, probably about 1050; but all that part of it which extends from the Eastern extremity to the entrance of the nave, was rebuilt in its present state by Henry III., who laid the first stone of the present Abbey in 1220; the central tower was rebuilt in 1245; and, in 1269, the Eastern end, with most of the transept and choir, was completed and dedicated. The nave was carried on slowly afterwards, and it was not till 1498 that the circular windows were formed, and the Western front erected; the towers were not entirely completed till the time of Sir Christopher Wren, who finished them as they now are. The Chapel at the Eastern end, which was built by Henry VII. to contain the tomb of himself and his Queen, was finished about 1512.

The general plan is that of a Latin cross, of which the nave is 234 feet long from West to East, and 90 feet wide; the transept is 225 feet long from North to South, and 100 feet wide from East to West. Beyond the transept towards the East are five Chapels, which occupy an extent, from West to East, of 196 feet. That of Henry VII. is at the Eastern extremity, and terminates in a semicircle, and there are two others on each side between this and the transept. The cloisters are of a rectangular form, 154 feet long from West to East, and 142 feet from North to South; and consist of an arcade enclosing an open court in the angle between the Southern wing of the transept and the side wall of the nave. And at the South-Eastern angle of the same transept is the Chapter-house, an octagonal building 74 feet diameter.

The nave and transept are divided as usual by rows of clustered columns, and the choir is in the central division of the nave, near its intersection with that of the transept.

The Western front is divided into three parts vertically; in the central division is the entrance, which is splayed and vaulted in the pointed form within the thickness of the wall; and above this is a great window divided by six vertical and four horizontal mullions. A gable, in which is a small triangular window, crowns this part of the front; but both the gable and the great Western window are of later date than the rest of the nave. On each side of the central division is a tower 225 feet high, standing on a square base, and divided into four parts or stories, containing windows with pointed-arch-heads, and terminating at top in a crocketed pinnacle at each angle. The faces of the towers are divided vertically into three parts, of which the exterior ones project beyond that in the middle, and are ornamented with rows of panels. These faces are the work of Sir Christopher Wren, and the style in which they are executed is much too simple for the rest of the building. The buttresses on each side of the central division of the façade are adorned with niches and canopies.

Along the Northern side of the nave is a row of graduated buttresses connected with the walls of the aisle and nave by arched ribs; between these buttresses is a tier of tall pointed windows divided into two parts by mullions, and over them is a row of triangular windows with three cinquefoil apertures in each. Above these are the clerestorial windows of the nave, which are similar to those of the lower tier; and the walls both of the nave and aisles are crowned by battlements.

The Northern front of the transept is a rich specimen of the pointed style of Gothic Architecture, and is divided horizontally, between the flanking buttresses, into four stages. In the lower are three entrance doorways, of which the middle one is higher than the others, and each is covered by a pointed arch, the sides of which are formed upon those of an equilateral triangle; over the side-doorways is a row of cinquefoil-headed panelling; and a horizontal row of pierced cinquefoil apertures at the level of the top of the central doorway terminates this division above. In the next division are four deep recesses covered by obtuse, cuspid arches; above them is a tier of small, cuspid arches springing from pillars, and, over this, is a perforated battlement. The third division contains a great circular window, divided into sixteen parts by radiating mullions, and the spandrils of the window are filled with roses and trefoil-headed leaves. The last division is crowned by the gable or pediment of the roof, and contains three pointed arches resting on pillars, and enclosed within the mouldings of one large arch of the same kind. The height of this front from the pavement to the apex of the pediment is 140 feet. The buttresses at the angles of the upper part of the transept are richly ornamented, and terminate in octangular pinnacles; curved ribs extend from these buttresses to those which are attached to the side walls of the transept, and the latter terminate in the same manner.

The Architecture of the exterior of the Eastern Chapels is similar to that of the nave; but Henry the VIIth's Chapel is much more enriched.

The pillars of the nave consist, each, of eight slender shafts surrounding a circular column; in those which are of the more ancient workmanship, that is, of the time of Edward I., the shafts are completely detached, but the bases and capitals are united; the latter are circular, and the pedestals form an entire mass: the more modern columns are surrounded by two fillets dividing them into three parts horizontally, and the small shafts have octagonal capitals and plinths. From the capitals of the columns spring the side arches of the nave, the radii of curvature in which are greater than the intervals of the pillars. The mouldings of the curved sides of the arches are deeply cut, and above the extrados is a concentric rib, or label, as it is called, which springs from a corbel head on each side. Above this arcade is a horizontal string separating it from the arcade of the triforia; this consists of a row of double trefoil-headed arches springing from small columns, and each pair inscribed in a simple pointed arch. From the capitals of the lower range of columns rise slender triple shafts, and from these spring the ribs of the groined work, formed by the intersections of equilateral ridged vaulting over the nave. The crown of this vaulting is 100 feet high from the pavement, and that of the side aisles is 47 feet.

The edifice built by Henry VII. is divided into a nave and two side aisles, and at the semicircular extremity are five small Chapels; it is surrounded at intervals by octagonal buttresses, 64 feet high from the pavement, ornamented with several courses of panels, niches, and tabernacle-work, and crowned by enriched pear-shaped pinnacles. The whole space between every two buttresses is occupied by windows from top to bottom; those along the sides are broken into three faces, and the others into six. The roof of the aisles is 25 feet from the pavement, and consists of a groined vaulting, having the spandrils rounded in a convex form, and ornamented with fanwork panelling; and from the vertices of the groining descend pendent spandrils, or masses of stone of a conical form with the points downward, ornamented in a similar manner. The vaulting of the nave is 63 feet 7 inches from the pavement, and its groins are enriched with fanwork and a triple row of pendents. The octangular buttresses of the nave are 96 feet high, ornamented like those of the aisles, and arched or flying buttresses extend from them to the latter over the roof of the aisles; these are pierced with beautiful quatrefoil and sixfoil apertures inscribed in circles, and the extradosses are ornamented with sculptured lions, dragons, and greyhounds. The walls of the nave, which contain great pointed arch-headed windows, are crowned by a band of panels and a perforated parapet. A plan, transverse section, and elevation of the Eastern extremity of this Chapel, are given in pl. xx. The whole of the exterior has been restored, with great delicacy of execution and strict attention to the original style, within the last few years.

The Chapter-house, at Westminster, which was built by Henry III., is of an octagonal form, and the walls are strengthened by projecting buttresses. The entrance from the cloisters is under two obtusely-pointed arches resting on a pier in the middle, and circumscribed by one large pointed arch which springs from three columns on either side. The inner mouldings of the small arches are sculptured, from the ground to the vertex, with branches and foliage, and over the extrados is a weather moulding springing from corbel heads.

King's College Chapel at Cambridge.

Two splendid Chapels, the one at Cambridge, and the other at Windsor, may terminate this account of the ancient Ecclesiastical edifices of England; since their completion took place in the latest period of Gothic Architecture. King's College Chapel, at Cambridge, was begun by Henry VI. about the year 1443, and is one of the most magnificent examples of scientific construction, as well as of Architectural beauty, in the Kingdom. The plan is a simple rectangle, and at the exterior angles of the fabric are four octagonal towers, with perforated ornaments, terminating in pear-shaped pinnacles crowned with finials. There is no division in the interior, and the vaulting, which was executed in the time of Henry VIII., is of stone, ornamented with fan-tracery. The entrances at the Northern and Southern extremities are covered by low arches, obtusely pointed at the vertex, the ribs of which are sculptured with deep mouldings; and on each side of the aperture is a small pillar, from the capital of which springs an elegant canopy, the sides of which are in the form of curves of contrary flexure, meeting in a point at the vertex; these are ornamented with crockets, and end, at top, in a rich finial. The windows are broad, with low pointed arch heads, and, with the exception of that at the Western end, are filled with painted glass, which produces a soft and pleasing light in the interior of the building.

Chapel at Windsor.

St. George's Chapel, at Windsor, is another example of this highly enriched style of Architecture, and was finished about the tenth year of Henry VIII. Its plan is in the form of a cross, the transept projecting but little beyond the side walls, and ending, at both extremities, in five sides of an octagon. The nave is divided into a centre and two aisles as usual, and the arches are of the low pointed form: bell-shaped spandrils rise from the pillars on each side of the central division, and are covered with fan-tracery up to the vault, the middle part of which is ornamented with curious panelling and pendent spandrils. The walls of the aisles and nave are finished, above, with perforated parapets.

Ecclesiastical buildings in Scotland.

The best remaining specimens of Gothic Churches in Scotland are, the Cathedral of Glasgow, Melrose Abbey, Roslin Chapel, and the Chapel of Holyrood. The first two were, probably, erected in the XIIth century, and the last two in the XVth. The Cathedral of Glasgow consists of a rectangular body 319 feet long, 63 feet broad, and 83 feet high, with one wing only of a transept; about the centre of the building is a square tower supported by four pillars, and, above it, an octangular spire, the height of which from the pavement is 225 feet. At the Western end of the building is another square tower, the pavement of which is supported on groined arches, and has a circular opening in the middle to receive a flight of steps.

Cathedral of Glasgow.

Melrose Abbey.

Melrose Abbey, which is said to have been founded by King David, in 1136, has the figure of a cross on the plan; it is 258 feet long, and 137 feet broad, and was crowned by a tower over the centre. The vaults of the roof are groined, and the ribs intersect each other, so as to produce an elegant tracery on the interior surface; and, besides solid buttresses at the angles of the building, the side walls are strengthened by flying buttresses of light construction. The windows are of the highly-pointed form, and the principal of them are divided by four vertical mullions; the extradosses of the ribs are ornamented with crocketed pediments of contrary flexure meeting in a point at the top, and the walls and buttresses have been adorned with tabernacle-work of a simple and elegant kind. This interesting edifice is now lying in ruins.

Chapels of Roslin and Holyrood.

The Chapels of Roslin and Holyrood are also in ruins; the latter, which was founded about 1440, had its walls strengthened by elegant, flying buttresses, and ornamented with tiers of small, pointed arches resting on slender pillars. The principal windows were divided into two apertures by pillars; those apertures were headed with pointed arches, one arch of a similar form enclosed both, and in the spandril between them were quatrefoil ornaments. Roslin Chapel must have been a beautiful specimen of Gothic Architecture on a small scale; its length is 69 feet, and breadth 34 feet. The roof was supported by arcades springing from two rows of clustered columns, and the vault over the centre division was sculptured with great taste and elegance.

We have already (chap. ii.) mentioned the buildings which usually accompany the Gothic Cathedrals; *viz.* the Baptistery, the Cloisters, &c., but we think it worth while to give here a general description of the Chapter-house, because some of these edifices are remarkable for elegance of design and richness of embellishment.

Chapter-house.

The Chapter-houses seem, originally, to have been of a rectangular form, like those of Durham, Gloucester, and Peterborough, all of which were built in the XIIth century. Subsequently, their plan was polygonal, and of this kind it is probable that the first was the Chapter-house at Lincoln, which was completed in the year 1200; afterwards, were built those of Salisbury, Worcester, York, and Litchfield, which, with many others, were imitations, as is supposed by Mr. Essex, (*Archæologia*, vol. vi. p. 170.) of the circular Churches of the Knights Templars erected at the close of the XIIth century; and these were, as probably, imitations of that erected over the Holy Sepulchre at Jerusalem.

The Chapter-house at Lincoln is a regular decagon, 60 feet diameter in the interior, and 42 feet high, with a clustered pillar in the centre composed of ten fluted columns of Purbeck marble, surrounding a stone pier, and standing on one pedestal. The capitals of these columns are elegantly sculptured, and, from above, spring twenty ribs which meet as many coming from the rentrant angles of the building; the intersections on the ceiling are connected by a similar rib, which forms a decagon about the central column, and the ribs from the angles are supported by clustered columns which rest on highly ornamented brackets. It is covered by a lofty pyramidal roof; each angle is strengthened on the exterior by a buttress terminating in a pinnacle, and ornamented with small pediments and crockets; arched buttresses extend from these to as many plain massive piers at a considerable distance from the walls.

We conclude with an account of the monumental crosses of our ancestors, which are to be considered as connected with the subjects contained in the present Chapter, and, therefore, the description may with propriety be introduced here.

Crosses.

From an early time the practice seems to have been general of erecting Crosses in public places to commemorate remarkable circumstances, and particularly to mark the graves of persons deceased. But those which are deserving of notice as Architectural objects, are a sort of monumental edifices erected in places wherein the body of a deceased Prince has rested for a time, in its passage to the place of interment; and some of these still remain as testimonials of the grief and piety of the surviving relatives. In 1285, Philip III. of France caused several to be erected between St. Denys and Paris, on the occasion of conveying the remains of his father, St. Louis, to interment; but they are all destroyed. In 1296, when Eleanor, the Queen of Edward I., died, her body was brought to London, and at the place wherein it rested each night during the journey, the King caused a building to be erected to her memory; of these, only three now remain; *viz.* those at Geddington, Northampton, and Waltham, which are in an imperfect condition, though still exhibiting great beauty in the design and taste in the execution.

Each building is octangular on the plan, and stands on a platform elevated a few feet above the ground, from which there is an ascent by a flight of steps on each side; the whole is divided into several stages by horizontal mouldings, each part less in breadth than the one below it, and the upper one is a pinnacle surmounted by a cross, from which this kind of monument took its name. These edifices, which from their gradual diminution upwards produce a graceful effect, are adorned with niches and canopies richly sculptured, and containing statues of the Queen; and from them the ornamented tabernacle-work employed about sepulchral chapels, shrines, and the like, is supposed to have had its origin. Crosses afterward became common, and were erected in many markets and other public places about the Country, where they served occasionally as pulpits from whence the Clergy preached to the people assembled about them in the open air.

CHAPTER IV.

Domestic and Palatial Architecture of England during the Middle Ages.

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The domestic Architecture of Europe must have been in a very low state from the first establishment of the Gothic Monarchies on the ruins of the Roman Empire, to the extinction of the Feodal system about the time of Charles V. The residences of the Princes and Prelates during those turbulent times were Castles; that is to say, edifices fortified to resist a siege; the houses of the inferior gentry were mostly of timber, till about the time of Henry VII., when brick came into use in England. In cities, also, the houses of the merchants and traders seem to have been of wood and covered with thatch.

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In our *Miscellaneous Division* we have already given some account of CASTLES. They were generally constructed of stone; a ditch surrounded the whole; within this was a wall having towers at intervals, which, besides the purposes of defence, served to lodge some of the officers attached to the service of the proprietor, and occasionally they were capacious enough to serve for the ordinary dwelling of the proprietor himself and his family. In some part of this wall was the gate forming the principal entrance, which was flanked by a tower on each side, and within it was the Chapel and the state-apartments, besides dwellings for servants or retainers, and rooms for stores: in some part of the interior, generally on an eminence, was a second Castle, called the Keep, to which the proprietor retired in case of siege.

There seem to have been but few Castles in England before the Norman Conquest, and that circumstance is supposed to have facilitated the subjugation of the Country; but in the reign of King Stephen a great number were constructed. The style of building in these edifices seems to have been the same as that which prevailed all over Europe during what are called the Middle Ages.

The exterior gateway was covered by a semicircular arch quite plain, because in such a situation any ornament would have been entirely misplaced; but those within the defences, which consequently might without impropriety receive a certain degree of embellishment, were made to correspond in form and ornament with the doorways of Ecclesiastical buildings of the same Age. Within the gateway was a narrow vertical channel cut in the wall on each side, in which the portcullis was drawn up or let down.

The principal apartment of a Castle was the Great Hall, wherein the proprietor entertained his friends and vassals on particular occasions; this room, which was rendered a little ornamental, had one part of the floor (the dais) raised above the rest, and in this part the principal guests were seated. The Chapel was constructed like other Ecclesiastical edifices, and the kitchen was generally a spacious building, but the ordinary rooms seem to have been small and unadorned.

The Keep of Rochester Castle.

The Keep of Rochester Castle, which was a general place of residence for the proprietor, and the walls of which still remain, will give some idea of the interior of such buildings. The plan of the Keep is a square 80 feet long in each direction, with a projection on one side 40 feet long and 20 feet from the wall, serving as a vestibule: the whole height of the Keep is 104 feet, and it is divided into four stories or tiers of apartments. The walls are 14 feet thick, and in them are galleries 5 feet wide, covered by vaulted roofs and surrounding the building on the three upper stories. At each angle of the building is formed a square tower, the faces of which project a little from the general faces of the wall; and in two of them are winding-staircases leading from the floor next above the ground quite to the top of the Keep. The gallery was lighted towards the exterior by loop-holes cut through the wall, and semicircular-headed apertures towards the interior communicated with the apartments. The interior of the building was divided into two equal parts by a screen-wall extending across it from bottom to top, in which were two doorways of communication, one on each side of the centre, except on the third story from the bottom, where the screen was cut away to form four semicircular-headed apertures. The archivolts of these, spring from massive cylindrical pillars, and are ornamented with the Norman zig-zig, and the intrados of each is cut in a serrated form; the interval between every two pillars is occupied by a wall reaching not quite so high as the capitals, and the space between the top of this wall and the soffit of the arch is open. A door of communication is made between two of the columns, and consists of a semicircular arch, the vertex of which is about as high as the top of the wall between the great columns; this arch rests upon two short columns, and the part between the extrados of this arch and the intrados of the great one is also open. In the middle of the great screen, and extending from the top to a well under the bottom, is a hollow cylinder formed in the wall, by which water was raised to the several stories of apartments, where it was received through apertures made in the wall on each floor.

In the interior faces of those two walls of the Keep which are opposite the screen-wall, a chimney is formed on each floor; this is a cylindrical recess terminated above by a semicircular arch resting on two dwarf pillars, and on each side is another pillar supporting a sort of cornice above the crown of the aperture. A funnel left in the wall suffered the smoke to escape from the upper part of the recess to the exterior of the walls of the Keep. The towers at the angles stand 14 feet above what was the ceiling of the upper story, or general roof of the building, and between them is a parapet wall crowned with battlements. The approach to the vestibule was by a flight of steps extending as high as the first floor above the ground, at the top of which was a drawbridge in front of the entrance. The doorway between the vestibule and the body of the Keep was closed by a portcullis, and one of the winding-staircases was in the adjoining tower. The floors of the rooms are entirely destroyed, but the rows of notches in the walls for the lodgements of the great beams are very visible.

The Castle is said to have existed in the year 765, but the present Keep was built by Bishop Gundolph, at the end of the XIth century, of Kentish rag-stone, except the angles and the window-frames, which were of a sort of stone brought from Caen, in Normandy.

Castles of Caernarvon and Conway.

The Castles of Caernarvon and Conway were built by Edward I. to serve as Palaces or Fortresses; and the beauty of the scenery surrounding them must have rendered a residence there as agreeable as was compatible with the restraints which a building enclosed by guarded walls must necessarily have imposed on its occupiers. Conway Castle is in the form of an irregular pentagon, and one side joins the Keep, which is square on the plan: at every angle both of the Castle and its Keep, is a strong round tower, and the approaches are protected by outworks. The Royal apartments were on one side facing the river, and at the foot of the wall is a terrace supported by a part of the rock which here rises abruptly from the shore. The style of this front is stated by Mr. Mitford to resemble a house which Palladio might have built, rather than what we consider as peculiar to a Gothic edifice. From the face of this wall projects an oriel or bowed-window of elegant workmanship, and the interior of the apartments appropriated to the Royal residence is executed in the style of the Ecclesiastical edifices of that day.

Under the Edwards, the English Nobility seem to have partly abandoned the Castles of their ancestors, and to have adopted the Palatial form for their dwelling-houses. The remains of the more ancient structures of this kind are, however, few, and the precise age of any of them is uncertain; and they have suffered so many alterations that it becomes impossible to communicate a satisfactory description of them. We perceive that they contained a number of rooms distributed without regularity, and the general appearance was similar to that of the Castles; though the turrets, battlements, and other features were such as could only serve as ornaments.

From the time of Edward I. to that of Henry VII., observes Mr. Strutt, the common houses were built of wood; there was a porch before the principal entrance, and within was a great hall, with large parlours adjoining: the framework consisted of beams of timber of enormous size. In cities and towns, each story projected over the next below, and the roof was covered with tiles, shingles, slates, or lead. But the perishable nature of the materials has necessarily long since brought them to ruin.

Westminster Hall.

Westminister Hall is a remnant of the most ancient Palatial edifice in England, having been originally, perhaps, part of the Palace of Edward the Confessor; it was probably rebuilt or repaired by William Rufus, who is said by Matthew Paris to have had his first Court in his new Hall at Westminster after his return from Normandy. By the same author he is said to have expressed an intention of building a new Palace; but it does not appear to have been executed till the reign of King Stephen, and then only in part. The Palace erected by this Prince was burnt down in the reign of Henry VIII. The lower parts of the present side walls are remains of the Hall of Rufus; but all above is the work of Richard II., who rebuilt the Hall in 1399.

The plan of the Hall is a rectangular parallelogram, 97 feet 8 inches wide from East to West, and 238 feet 8 inches long. The Northern or principal front is broken vertically into three parts, of which that in the centre is 47 feet wide; in this is the doorway with a great window above, and it is crowned by a high gable pediment, the vertex of which is 92 feet from the pavement; the sides of the pediment are ornamented with crockets, and at the apex is a small tabernacle on a polygonal base, and crowned by a pinnacle. The division on each side of the centre is a square tower, 72 feet high, crowned by battlements. The entrance porch is formed in the thickness of the wall; its sides, which are splayed outward, are ornamented with slender columns, and from those at the angles spring the ribs of an elegant groin-work which covers the vault of the porch. The front of the porch is covered by an obtusely-pointed arch rising from clustered columns; this arch is circumscribed by a rectangular frame, and each spandril is ornamented with a shield formed in a quatrefoil ornament. All the lower part of the façade is ornamented by a tier of niches intended to contain statues, and each is covered by a projecting canopy. In the second story of each tower are also two niches with canopies, and between the niches a low pointed arch divided into four apertures by a vertical and transverse mullion.

The present interior facing of the side walls was executed under the direction of Mr. Kent; this is ornamented with rows of piers, from the capital of each of which springs an arched rib of timber, meeting a horizontal piece of the same material projecting from the top of the wall, and terminating in the figure of an angel also in a horizontal position; from the extremity of this arched rib springs another which meets the corresponding rib from the opposite side of the Hall in a point over the middle. Above the vertex of the timber arch thus formed is a horizontal collar-beam which meets the rafters of the roof, and over its middle point is a king-post reaching to the vertex. Between these ribs and the wall and roof of the building is another rib, which extends in one continuous curve from the capital of each pier to the apex of the arch under the collar-beam; and in the open spandrils of the several ribs are rows of vertical pillars with cusp heads in wood-work over their intervals. The thrust of the roof is counteracted by flying buttresses. Mr. Pugin supposes that the roof was originally supported by rows of columns, for, he observes, it is not likely that the Architects of that day would form one capable of covering so great a span without such support.

The great Northern window of the Hall was built in 1380; it is 30 feet wide and 48 feet high, in the form of a pointed arch springing from the vertical sides of the window at 27 feet 9 inches from the sill; consequently the radius of each curved side is equal to 21 feet 3 inches, or to about two-thirds of the span. The window is divided into three parts by two vertical mullions, and each part into three others by two of smaller size; all the mullions reach to the top of the arch, one great transom crosses them at right angles, and a branch from each principal mullion makes, by uniting with the curved side of the head of the window, a pointed arch over the right and left compartments. The tops of the apertures between the mullions are covered with trefoil cusps.

At the Southern extremity of the Hall is a large window similar to that over the doorway of the Northern front. The whole of the latter has been recently restored, nearly in conformity with the original work executed in the time of Richard II., but the forms of the crockets and finials do not seem to coincide accurately with those exhibited in Hollar's view of this edifice. The range of niches extending from each side of the entrance along the fronts of the towers, together with the decorative panelling overspreading the whole to the height of the cornice, confer an air of superior grandeur on the façade.

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In the reign of Henry VIII. the residences of the Nobility had not entirely lost the military character which formerly prevailed in the Country, and the edifice erected, partly by Cardinal Wolsey, at Hampton Court is the best specimen remaining of the style of building in his day. This, which afterwards became a Royal residence, was begun in 1514, and in the time of the above-mentioned Monarch it is said to have had five spacious courts; it now, however, consists of three complete quadrangles only, besides the buildings used as offices. In the centre of the entrance-front is a square tower, flanked by an octagonal turret at each angle higher than the rest of the building; through this tower is a grand gateway formed by an obtusely-pointed arch, over which, both on the front and rear faces, is a rich oriel; the wall is crowned by a battlement of open work, and each of the turrets terminates in an octagonal pinnacle, the faces of which are curves of contrary flexure. On the right and left of the tower the buildings in this front have been partly modernized, but at each extremity is one of the old gables, the sloping sides of which are ornamented with griffins; from these extremities the wings project towards the front at right angles to the body of the building, so that the whole forms three sides of a parallelogram.

The first quadrangle, which is entered by the gateway above-mentioned, consists of dwelling-houses, the walls of which are crowned by embattled parapets; the windows are square, and the doorways covered by plain arches. In the centre of the front, opposite the entrance, is another tower similar to the first but smaller, and flanked also by octagonal turrets crowned with battlements. Through this tower also is an arched passage, over which is an oriel less embellished than the former; this passage leads to the second quadrangle, which is smaller than the first. The left side is occupied by the Grand Hall, which was built by Henry VIII.; this is covered with a lofty roof, its sides are strengthened by buttresses, and in its walls are pointed windows with mullions proceeding straight to the top. On the right-hand side of the Court is a colonnade consisting of coupled Ionic columns, erected by Sir Christopher Wren.

A third gate-tower, in a line with the two former, contains a passage leading to a third quadrangle, which is surrounded by an arcade on piers supporting the fronts of the buildings; the whole of this quadrangle was entirely modernized in the time of William III. The ceiling of the gateway is ornamented with rich fan-tracery, and in the passage is the staircase leading to the state-apartments.

The walls are built of red and dark-coloured bricks, so arranged as to chequer the exterior in diagonal lines, and are crowned by perforated and plain battlements; the windows, doorways, and principal ornaments are of stone. The windows of the ancient building are disposed without regard to symmetry; the frames are rectangular, and, in general, the breadths are greater than the heights; they are divided vertically by one or more mullions, and some of them are again divided horizontally by a transom near the middle of the height; the lights or apertures are terminated above by obtusely-pointed arches within the rectangular frames. An elevation of part of one side of the first quadrangle is given in pl. xx.

The timber-roof of the hall exhibits a fine display of constructive skill; each frame supporting the exterior covering is composed of two systems of beams placed one below the other, and each consists of four inclining timbers, of which the two upper meet in an obtuse angle over the middle of the breadth of the hall, and the two lower rest on the tops of the side walls. The inclining sides of the upper system are connected by two horizontal tie-beams, one at the foot of the upper pair, and the other about the middle of the lower, and the apex of the lower system falls at the centre of this tie-beam. At the foot of the two systems, on each side of the building, is a horizontal timber, projecting from the wall towards the interior as far as about one-quarter of the breadth of the hall; the extremity of this is supported by a curvilinear spur, the foot of which is inserted in the wall below; and, from the same extremity, on each side of the building proceeds a curvilinear rib of the hyperbolic kind to the apex of the lower system, forming together an obtusely-pointed arch. Rigidity is given to the whole frame by vertical timbers between the curved ribs and the exterior system of beams; and below each foot of the hyperbolic ribs is a pendent ornament in wood work. A section of this roof is given in pl. xx.

Most of the Colleges at Oxford are buildings surrounding quadrangular areas, and are executed nearly in the style of the ancient works at Hampton Court.

The style of domestic Architecture which prevailed in England during the reign of Elizabeth, and even of James I., bore considerable resemblance to that which has been just described, though an imitation of the Italian Architecture is supposed to have been introduced into the Country as early as the reign of Henry VII.

We conclude this Chapter with a description of the two most prominent features in the ancient mansions of this Country, *viz.* the Oriels and the Fire-places, of which some interesting specimens are still in existence.

Oriels.

The former are windows projecting beyond the front of the edifice and supported only by the masonry of the wall; the period of their invention is unknown, but their antiquity is considerable, for there is one such, constructed on a face of Conway Castle, which was built by Edward I. They were formed sometimes of three, sometimes of five sides of an octagon; of the latter kind is the beautiful oriel-window in what is called John of Gaunt's Palace, at Lincoln, which was built in 1390. According to the description given by Mr. Pugin, the bracket sustaining the frame of the window is covered with sculpture, and divided into four tiers. In the lowest is represented an angel, the second contains the heads of a king, a queen, and a bearded man; the third is a course of foliage; and in the fourth is represented foliage with six figures, one under each of the abutments or upright pillars of the window. At the bottom of the window, on each side of the octagonal bow, are two quatrefoils in panels; the parts which contained the glass terminate in cuspid cinquefoils, and above each are crockets and a finial. The upright pillars of the window terminate, above, in pinnacles covered with sculpture.

In the Chancellor's house, at Lincoln, is a plain Oriel, consisting of three sides of an octagon, supported by a bracket ornamented with horizontal mouldings, and crowned by battlements. Each of the three lights, or windows, is divided by one vertical and one horizontal mullion, and over it is a rectangular label. This is a kind of weather-moulding forming three sides of a rectangle, of which that above the window is horizontal, and the lower extremities of the vertical branches, which descend on each side of the window, are again broken at right angles to form short wings turning from the window; in the present example these wings are in the lozenge form. A similar Oriel may be seen in the Palace of Hampton Court. In the Age of Elizabeth and James I. the Oriels were divested of nearly all the richness of sculpture which distinguished them at an earlier period, and they sometimes consisted merely of rectangular projections, of which the central one was much broader than the others, and parallel to the wall of the building.

The Oriels seem to have been originally intended to form a retired closet for prayer or meditation, or to afford an extensive prospect from an apartment; but, in the time of the Tudors, they were also accompaniments to the Great Halls of Palaces, and served as recesses to contain a sort of sideboard.

Fire-places.

The Fire-places in the ancient mansions of this Country were very large, and generally enriched with elaborate sculpture; we have mentioned some of a Norman character in describing the Keep of Rochester Castle, but these are far exceeded in magnificence by such as were erected at the time the Gothic Architecture was in its most florid state. Those of Tattershall Castle, in Lincolnshire, which was built in 1440, are described by Mr. Pugin as having the apertures formed in elliptical arches with elegant mouldings; above these are legendary compartments and heraldic insignia. The mantelpieces have battlemented tops, and above them are segmental arches formed in the wall to support its weight. The Fire-places at Hampton Court also are distinguished by a profusion of the richest sculpture. The chimneys of this period assumed a picturesque form, and resembled pillars or turrets; they were square, octangular, or circular on the plan, and placed in couples or groups touching each other at the bases and summits only; the shafts were ornamented with lozenges and mouldings in zig-zag and spiral directions, and sometimes crowned by battlements. See Pugin's *Specimens of Gothic Architecture.*

CHAPTER V.

General Description of the Saxon and Norman-Gothic Architecture.

Absence of Orders in Gothic Architecture.

A grand distinction in the general system of the Gothic Architecture from that of the Greek or Roman, is that while the former possesses certain features peculiar to itself, there is in it a want of the Orders under which buildings differing from each other in style may be classed. In the same edifice are columns of different kinds, and having no constant proportion between their diameter and height; the ornaments also are extremely arbitrary, for in the same column the mouldings of the Doric Order and the leaves of the Corinthian or Composite capitals, with grotesque figures of men or animals, are all confounded together.

Style of the ancient Churches in the North of Europe.

Two very distinguishable styles of the Northern Gothic Architecture may be observed at first sight; the most ancient of which seems to have been in use till the XIIIth century, when it gave place to the other, which, in its turn, prevailed till the XVIth century. The former of these is considered by Dr. Moller as having originated in the South of Europe; and as bearing great resemblance to the Roman style in solidity of construction, in the flat or low pitched roofs, and in the semicircular form of the arches and vaults which had been substituted for the horizontal entablatures of the more ancient buildings. Specimens of this style he considers to be exhibited in the Cathedrals of Aix la Chapelle, Spires, Worms, and Mentz; all of which were executed in the Xth and XIth centuries. These Churches seem to be imitations of the Basilicæ of the Romans, with the addition of the transverse rectangle, and over the intersection of the arms of the cross a louvre or turret open at the sides. The walls were massive and the windows small: the pillars of the nave were short, and supported arches, which, as well as those of the windows, were semicircular. The nave was high, and covered with a groined vaulting, and in the upper part of the building were rows of small pillars attached to the wall for ornament. Above the vaulting was a flat timber-roof covered with lead or gilt tiles, and in the whole exterior of the building a system of horizontal lines predominated. The ornaments were generally of antique origin, and the bases of the columns, of the Attic kind, were correctly formed. The Western front was crowned by a pediment of low elevation, and perforated by a circular aperture which, probably, was the origin of the large rose-window, afterwards so conspicuous in Gothic edifices. The pillars of the interior were beautifully formed, and were probably taken from Roman buildings, but disposed without regard to symmetry, different forms being employed in the same range, and the arches above them being either very small or very large when compared with the size of the supports. The pavements were composed of irregular fragments, and the walls covered with rude paintings. Such are the characteristics of the Churches of Germany and France before the XIIth century.

In the more ancient Churches of Normandy, which are referred, we know not on what foundation, to the time of Charlemagne, the sides and ends present, each, on the exterior, the appearance of one or more great panels between plain piers of small projection, and a general horizontal band joining their upper extremities; these bands are crowned by horizontal cornices, which are sometimes supported by heads like corbels. The inferior edge of the band above-mentioned is frequently ornamented with a row of blocks, like dentels, or of small semicircular notches. The circular extremities of the Churches are frequently covered by very high conical roofs projecting considerably over the walls, and between the piers, if they may be so called, are two or more rows of semicircular arches springing from small columns, and having their archivolts divided in several faciæ. Examples of this style may be seen in many of the Churches in this Province, and particularly in those of St. Paul, at Rouen, and of St. Nicholas, at Caen.

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At a period preceding the Saxon conquest of Britain, the Churches of this Country seem to have been made of willow-rods interwoven; such, at least, is the opinion of Dr. Sayer, and, according to Fuller, the dwelling-houses of the Saxons themselves, and even some of their Churches, he mentions particularly the Church of Glastonbury, were thus constructed. The style of the Cathedral of Hexham, as we have said, was probably borrowed from that of the Constantinopolitan Churches, but the generality of the Saxon Churches were of a more simple character; they consisted, like those before-mentioned, on the Continent, of a rectangular nave with a portico at the Western end; the Eastern end was hemicylindrical, like the place of the tribune in the Basilicæ, and the nave was divided into three parts by two arcades, above which were galleries. The arches were semicircular, and rose immediately from the capitals of the columns. The shafts of these were very massive and generally cylindrical, though columns of a different form seem to have been sometimes used. In each face of the tower of Earl's Barton Church, in Northamptonshire, is an aperture divided into five parts by small columns resembling balusters with simple plinths and abaci, and surrounded in three places by astragals, between every two of which the shaft is formed like a barrel. (See Britton's *Architectural Antiquities*, vol. v.) The walls of the buildings were thick and without buttresses; the principal doorway was crowned by a semicircular arch resting on pillars having sculptured capitals, and the archivolt itself was formed with various mouldings, and sculptured with objects in relief.

The Cathedral at Old Sarum probably corresponded in the plan with the description above given; for, from what can be traced of the foundation, it seems to have had a nave and two side aisles, and the Eastern end was semicircular.

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The rudeness and imperfection of the sculpture which ornamented the Saxon buildings in England, as well as the similar buildings on the Continent, and its resemblance to that which is found on some of the Roman edifices, are considered as proofs that such sculpture was only a feeble imitation of that which abounds on the Roman edifices; but it must be acknowledged that much of it, particularly the zig-zag ornament and the fretwork, is the invention of the Northern artists themselves. According to Dr. Milner, the Saxons, having a taste for embellishment, copied the ornaments of the Roman Corinthian Order, leaving out the richer parts of the foliage, or substituting the forms of men or animals, which were more easily executed: and he observes, that the Saxon mouldings also have their archetypes in the later buildings of the Romans, from which, no doubt, they were borrowed. And since what has been said of the sculpture is equally applicable to the designs of the edifices themselves, the construction of which is of the same period, it may be inferred that these designs have been taken from the very works which supplied the ornaments. In fact, the construction of the Anglo-Saxon Churches is expressly named by the writers of that day, *Opus Romanum*, and this must sufficiently indicate the source from which the construction was drawn.

Improvement of English Architecture by the Normans.

The Conquest of England by the Normans produced an improvement in the Ecclesiastical buildings of this Country. Previously to this event, the Churches had been suffered to go to ruin, and even the spirit of Religion is said to have been nearly extinct. The piety of Edward the Confessor indeed had induced him to labour for its revival in the minds of his people, and afterwards the obligations of the Conqueror to the Pope rendered it convenient to promote the interests of the Clergy. The result of the efforts of both Monarchs was a general repair of the old and the erection of many new Churches of considerable magnificence in various parts of the Kingdom.

Writers on the Ecclesiastical Architecture of this Country make a distinction, as we have before observed, between the Saxon-Gothic and the Norman-Gothic; but it will be evident, on comparing together the few examples we have of each, that almost the only difference consists in the works executed about the time of the Conquest being on a greater scale than those of the preceding Age, and more highly ornamented.

Style of the Anglo-Norman Churches.

The general plan of the Norman Churches was the same as that before described; the body of the Church was rectangular, its longest side lay in the direction of East and West, and the principal entrance was at the Western end; at or near the other extremity was a transverse rectangle directed from North to South, and over the intersection of the two branches of the cross was a tower, which generally served as a louvre or open lantern. This central tower does not appear to have existed in the more ancient English Churches, except perhaps in that at Hexham. In some of the Norman edifices a square tower was erected at the Western end, and in others there were two such; *viz.* one on each side of the entrance, and extending on the right and left beyond the side walls of the Church, but rising very little above the general roof of the building to which they were attached. The towers were without pinnacles, but were ornamented on the exterior by arcades, in tiers attached to the walls, and consisting of small arches, sometimes separate, at other times intersecting each other. The towers might have been at first intended to contain bells like those of the Italian Churches; but afterward, as is supposed by Mr. Bentham, they might have been built for the sake of the fine effect produced by their height and forms. The wooden rafters of the roofs of Churches were at first exposed to the view from the interior, but they were afterwards concealed in panels, which were painted in mosaic in several colours, as may be seen in the Cathedrals of Peterborough and Ely. The interior of the body of the Church was sometimes quite surrounded by attached columns and arcades, and along the nave and choir were two ranges of cylindrical pillars, one over the other, with semicircular arches springing from the capitals; the upper arcades formed the faces of the triforia over the aisles.

On the outside of the building appeared commonly two, sometimes three, tiers of windows, generally high and narrow; and the walls, as well as those of the towers, were ornamented with tiers of attached pillars and arches. The top of the doorway was sometimes horizontal, above it was a semicircular archivolt projecting from the wall, and between it and the top of the aperture were scriptural figures rudely sculptured in bas-relief.

The buttresses of the Norman Churches were generally rectangular on the plan, of small projection, and uninterrupted in their whole height. In some cases, the buttresses were of cylindrical forms, like columns of

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different diameters placed one on another, and the smaller above the larger, such are the buttresses of the tower of St. Peter's Church, at Northampton, at each angle of which are three clustered together.

In the Saxon and Norman Cathedrals, a Crypt, or subterranean Church, was a necessary appendage, and such substructions remain under the Cathedrals of Canterbury, Rochester, Winchester, and Gloucester; all of which are of the early Norman times. The interiors of Crypts are divided by parallel rows of piers, or of dwarfish and massive columns, from the capitals of which spring the arches which form the groined vaulting of the Crypt, and support the pavement of the edifice above.

The greater part of the Cathedrals of England, particularly those of Durham and Carlisle, contain specimens of this Norman, or late Saxon style, which prevailed here about a century and a half; *viz.* from the time of the Conquest, in 1066, to about the year 1200; the nave of the old Cathedral of St. Paul, in London, was of the same kind of Architecture. The basement story of the School and Library, at Westminster, exhibit also some interesting remains, which probably formed part of the Church rebuilt by Edward the Confessor; they appear to have originally composed an apartment 110 feet long and 30 feet wide, covered by plain groins formed by a hemicylindrical vaulting which rests on the piers in the wall and on a middle row of eight short and thick columns with square capitals variously sculptured.

Resemblance of the Saxon and Norman Architecture to the Lombardo-Gothic.

The more ancient Churches of England resemble the Lombard Churches in the plan and distribution of the building, in the general character of the columns, and in the ranges of arches formed for ornament against the faces of the walls; there is some difference, however, in the columns, and those in the Italian buildings approach in form and proportion nearer to the ancient Roman examples; the semicircular archivolts in the walls of the English Churches, as in Norwich Cathedral, and in the Church at Castle Rising, in Norfolk, spring sometimes from the alternate columns, and form intersections with each other, an arrangement which has not been met with in Italy. In the Chapter-house of Wenlock Priory there are as many as three tiers of intersecting archivolts over the columns in the faces of the walls; in this Church also the supporting columns are tripled, and within the intersections small arches spring from the capitals of those next to the wall. Under the sloping sides of the pediment or gable, the face of the wall is recessed, and within the retired part are Saxon columns, the lengths of which have been made various, in order that they may suit the inclination of the sides of the roof; a circumstance which corresponds exactly with a practice before adopted in the Cathedral at Pisa. We may, perhaps, therefore, be allowed to conclude that the English artists, in adopting the Southern style, have preserved the character of the features, but have taken the liberty of multiplying them in order to produce a higher degree of ornament in their edifices.

Forms of Norman Arches.

The arches of Norman and Saxon buildings, as well in the interior arcades as over the doors and windows, and those attached to the faces of the walls, were almost always semicircular, but some variations occur in their forms. The apertures between the columns in Earl's Barton Church are covered by elliptical arches; in the Church of St. Peter, at Barton-upon-Humber, in Lincolnshire, are two apertures separated by a square pier, and each crowned by two rectilinear sloping sides, like those of a pediment, which meet in a point at top; and in the tower of Barneck Church, in the same County, are a door and window terminating at top in the same manner: these circumstances render it probable that this kind of arch, if it may be so called, which, if it had been met with in an Egyptian building, might have been taken for one of the primitive specimens, was not uncommon in the edifices of those days. But, besides these, we may add, that a form, to which the name of the horse-shoe arch has been given, exists in several works executed in this Country in the Norman times. This must not, however, be confounded with the Moorish arch of the same name, the aperture of which is narrower at the foot than at some distance above; the English arches are semicircles, or semiellipses at the top and the sides, and are continued in rectilinear and vertical directions down to the capitals of the piers or columns on which they rest; such are the arches of Romsey Church, in Hampshire. In the doorway of Southweald Church, in Essex, is an archivolt whose extrados is exactly semicircular, while the intrados is of the form above described, though slightly marked. Over the doorway of Little Snoring Church, in Norfolk, is a triple arch, the interior of which is a semiellipse nearly; the second is of the pointed form, and the exterior is elliptical at the top, with vertical sides. (See Britton's *Architectural Antiquities*, vol. v.) The pointed arch is ornamented with the Norman zig-zag, and the whole is supposed by Mr. Britton, with great probability, to be a freak of some builder at a period subsequent to the introduction of the pointed arch in England.

Norman columns.

In the interior arcades of the Norman Churches the columns are cylindrical, or in the form of octangular prisms, and their heights, including those of the bases and capitals, are equal to from four times to seven and a half times their diameters, though cases occur in which the height is as much as eleven diameters. The bases sometimes consist merely of a square or circular plinth, but, in many cases, two or more plinths are placed one on another, and above them are narrow circular mouldings, which are frequently sculptured so as to resemble ropes. The shafts are sometimes plain, but often covered with ornaments in spiral and zig-zag grooves surrounding them; and at other times with rhomboidal or lozenge-formed panels sunk in the shaft. The interior of Durham Cathedral, the South doorway of Iffley Church, Oxfordshire, and the window in the Western end of Castle Rising Church, Norfolk, present elegant specimens of these ornaments; for some of which a prototype might be found in the Treasury of Atreus, in the paintings of Herculaneum, and in the mosaics of the Church of the Nativity, at Bethlehem. Columns of similar forms, with plain shafts, are to be seen in the porches of the old German Churches.

The simplest specimens of the Saxon or Norman capitals are, probably, such as those in the Crypt of Lastingham Church, Yorkshire; (pl. xvii. fig. 3.) these resemble baskets or vases placed on the tops of the cylindrical blocks which serve as columns; the lower parts are of a convex form, and either plain or ornamented with leaves; the upper part is cut so as to form a plain, vertical face under each of the four sides of the abacus, below the angles of which are formed small volutes or scrolls. Often, the abaci and vases are cut in eight vertical faces; and, in the oldest specimens of Norman Architecture, the faces are frequently decorated with rude sculpture representing centaurs, griffins, and other extravagances, as may be seen on the capitals of the columns in Iffley Church.

The intervals of the Norman columns, or the spans of the arches which rest upon them, are equal to about two diameters, and the breadth of the system of mouldings forming the arch varies from about one-half to two thirds of the diameter of the column.

The mouldings about the doors and windows of the Norman Churches consist of reeds and channels with concave or plane faciæ between them, to the latter of which various ornaments are applied; the concave spaces are either left unadorned, or upon their surfaces are placed roses and foliage with figures of birds, beasts, or grotesque heads of men, at intervals, as about the South doorway of Iffley Church; frequently the archivolts are covered with a profusion of zig-zags, and the soffits of the arches are notched to correspond with the forms of these ornaments. When the archivolt is not supported by columns, the mouldings and ornaments of the former are continued down the vertical sides of the aperture to the pavement; and if columns are employed, the ornaments either terminate on the capitals of the columns, or, after being interrupted by them, are continued down the shaft. An arch in Tickencote Church, Lincolnshire, and a doorway in the South aisle of Durham Cathedral, have been chosen to exhibit the manner of ornamenting the arched entrances to Norman buildings. See pl. xvii. figs. 1, 2.

The convex or reed-mouldings, whether rectilinear or curved, are either plain or sculptured in the form of ropes, or rather, so as to present the appearance of a cord wound about a pole; examples of this kind occur in the doorway of Hanborough Church, Oxfordshire, of Wimbolton Church, Norfolk, and of many other Norman buildings. The shafts of the columns themselves, and the astragal mouldings of their capitals, are often ornamented in a similar manner; for which a Roman authority may be urged, as they are represented in the paintings at Herculaneum, and exist in the Palace at Spalatro.

Besides the foliage and animal figures with which the Norman mouldings are enriched, several geometrical forms were frequently employed; these are classed under the heads of billets, hatchings, zig-zags, fretwork, and bosses.

The billet ornament consists of two or more courses of small cubical or cylindrical blocks disposed in the circumferences of concentric circles, if they are placed about the arched head of an aperture, or in parallel lines if along its sides; in the former situation the extremities of the billets, like the joints of voussoirs, tend to the centre of the curve. The extremities of the blocks in any one course are not generally placed in contact, but an interval is left between every two blocks, equal in extent to the length of one block, and the blocks in the next course are opposite the intervals of those in the first course. This disposition may be seen about a doorway in Bingham Priory, Norfolk, and about the windows of Steyning Church, Sussex, and of Castor Tower, in Northamptonshire. Sometimes, however, the ends of square blocks abut against each other in every course, and the courses are so disposed that the general profile of the whole moulding has the form of three sides of a hexagon; each side is broken continually, on account of the lateral edges of the blocks in any one course not being coincident.

The hatched-moulding is very similar to the form of the square billet-moulding, the profile of the whole representing three sides of a hexagon, but in each face is a series of triangular notches resembling such as might be cut by an axe. This kind of ornament is found along the face of a cornice, and on the wall itself, of Castor Tower, in Northamptonshire.

Zig-zag-mouldings.

What is called the chevron work, or zig-zag ornament, is very commonly employed in the archivolts of the Anglo-Norman doorways; it resembles a small reed-moulding broken so as to form a succession of salient and rentrant angles, the broken parts being of equal lengths, and inclined to each other at various angles from a right angle to one of 150 degrees. In some cases the reed is single, as in the doorway of Little Snoring Church, Norfolk; in others, the system consists of four or six parallel reeds on the front; and both of these kinds may be seen about the Northern entrance to Peterborough Cathedral. In some cases the system of reeds is continued from the foot of the arch to the ground along each side of the doorway, as in Iffley Church; and, lastly, two courses of zig-zags are placed beside each other with their salient angles in opposite directions, so that a course of rhomboidal spaces is left between the reeds.

Fretwork

The fretwork ornaments are a species of zig-zag, and were employed in similar circumstances; the most simple is a reed-moulding broken in parts alternately parallel and perpendicular to each other so as to resemble the outline of a battlement, an example of which occurs in Sandwich Church, Kent. In an arch at Ely, the parts form sides of equilateral triangles, the bases of which are alternately situated towards the intrados and extrados of the arch. This moulding, instead of a succession of angles, forms sometimes a waving line or curves of many flexures; in which case it is called a *nebula*, and such an ornament exists in a facia at Bingham Priory. The same name is given to a succession of small semicircular notches which join together at their lower extremities, and extend along the inferior side of a horizontal or curvilinear band; examples of these ornaments may be seen over the doorways of the Churches of Hadiscoe, in Norfolk, and of St. Julian, at Norwich.

Bosses.

The plain faciæ of archivolts and the sides of doors are occasionally ornamented with bosses in the form of small pyramids on rhomboidal bases; they are placed at certain distances from each other, and are usually distinguished by the name of nail-head ornaments, which they in some respects resemble. They are found in the arches of Ely and of Lincoln Cathedrals. Star ornaments may be considered as a variation of the last; they are disposed in one or more parallel or concentric rows, each figure consisting of four rays, like those of a star, in relief. They are found on many of the Norman buildings, and particularly on some of the Churches in Suffolk.

CHAPTER VI.

Opinions concerning the Origin of the Pointed Architecture.

Doubtful origin of the pointed arch

About fifty persons have written on the origin of that species of the Gothic Architecture, the principal feature of which is the pointed arch. The names and opinions of these persons are enumerated by Mr. Britton, in the Vth Volume of the *Architectural Antiquities of Great*

Britain, but among the latter there are only about twelve which may be said to be essentially different from each other. These examples of learned trifling exhibit various objects to which the cuspid arch can be likened, up to the keel of Noah's Ark; and the difficulty is not to form an opinion of the possible origin of the arch, and of the species of building to which it appertains, but to select that which appears the most probable. Each person has brought arguments to disprove the opinion of his predecessors, and his sentiment has been, in its turn, impugned by the next Writer. The impossibility of supporting any one opinion by an appeal to Historical evidence renders it unnecessary to lose time in the effort to determine a question which most persons are now disposed to consider as involved in impenetrable obscurity. But as it may be expected that something should be said on this head, we may be, perhaps, permitted to mention two or three of the most important suggestions.

Referred to the rectilinear pediment;

One party,—reflecting that to form a roof of masonry over any space the extent of which is greater than the length of such stones as could be conveniently obtained, it would be only necessary to take two stones, each greater in length than half the interval of the supports, and to place one extremity of each on the top of the pier, letting the other extremities meet above the middle,—considers this construction, from its resemblance to the pointed arch, as the prototype of that feature; and the passages in the Egyptian pyramids, which are thus roofed, are mentioned as proofs of the antiquity of this species of arch. It may be added that similar coverings to apertures occur in ornaments in many Saxon or Norman buildings, and particularly in the walls of St. Augustine's Church, at Canterbury, where the sides of the covering rest on the tops of small Saxon columns, the erection of which must have preceded the invention of the pointed arch with curved sides. But though this construction may have been the first step to the invention of an arch of masonry in general, or of the pedimented form of a roof, it cannot be considered as likely to have led to a change from the semicircular arch to that formed of two segments, since it must have been known from the earliest Ages; and no reason can be given why the change just mentioned should have taken place at the period assigned to the introduction of the pointed arch into buildings rather than at any preceding period.

to the Egyptian pyramids.

In Mr. Murphy's account of the Convent of Batalha, in Portugal, the pointed arch is derived from the pyramidal form of the Egyptian Tombs. This author supposes that, because the Christians buried their dead in Churches, the towers of the latter were made of a pyramidal form, in imitation of the Egyptian style; and he concludes that since the pointed arch is essential to this form, it must have been derived from it. But it has been replied to this argument that the most ancient Churches have not pointed steeples: and, since the burying of the dead in Churches was but a secondary object, it is not likely that Churches would be made to represent Tombs, nor, consequently, that the pointed arches were derived from the same source.

Supposed invention in the East.

It was an opinion of Sir Christopher Wren, and of several writers subsequent to his time, who, probably, relied too confidently upon his authority in a matter of which he might reasonably be supposed a competent judge, that the pointed style of Gothic Architecture was invented among the Saracens, and that from them it was extended to the North of Europe, either by persons returning home after the first Crusade, or by the Moors, who, having received it from Asia, introduced it into Spain when they made the conquest of that Country. This opinion is founded upon the fact that arches of a pointed form really exist in various parts of the East, and some of them in buildings of great antiquity; such as the Tomb or Chapel of the Virgin, at Jerusalem; the remains of a Church, at Acre; the Tomb of Abdallah; and the Hall of Joseph, at Cairo. In the façade of the first, is a Gothic pointed arch springing from columns, and there are two others on the staircase in the interior; the edifice is supposed to have been erected in the time of Constantine; but this is by no means certain, and even if so, it is very probable that the arches were constructed at a later period than the body of the building. The antiquity of the second ascends to the time of the existence of the Saracenic Empire, and it was undoubtedly built by the Christians while they had possession of this part of Syria; consequently, the pointed arch in it is as likely to have been copied from similar works before that time executed in Europe, as from any thing invented by the Arabians. The last two buildings have been already mentioned, and shown to afford no proof of the Asiatic origin of this feature. It may be added that the form of the pointed arches employed in the Saracenic buildings is different from that adopted in the North of Europe in being very slightly pointed, and in the aperture being narrower at the foot than a little above it: if, therefore, we suppose that the pointed arch originated in the East, it will appear surprising that those who introduced it into France or England should have so far altered its form as to make it spring vertically from the capitals of the columns which support it; and that not one example should occur, in this part of Europe, similar to those which are found in the Moorish buildings of Spain.

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It has been observed by Mr. George Sanders that, in some Cathedrals and Churches, where the semicircular extremity on the Eastern side is surrounded by an interior arcade, the columns from which the arches spring are not at the same distance from each other in that arcade as in the nave or choir. Therefore, when it was intended to keep the vertices of all the arches at the same height, if those in the nave or choir were semicircular, it would be necessary to make the others semielliptical; but this kind of curve not being easily traced, the artists would naturally fall into the method of giving to those arches the cuspid form, by making them consist of two segments of circles meeting each other in an angle at the vertex; and thus the pointed arch might originate. That such arches should be employed in this case is very natural; and we see, in the Cathedrals both of France and England, of which that of St. Denys, near Paris, and the Trinity Chapel, in the Cathedral of Canterbury, may be taken as examples, that they really were so; and obviously to obtain an equality of height with those in the adjoining choir or transept. But there is one objection to the opinion that the pointed arch originated from this circumstance; *viz.* that those which are so employed appear to have been erected subsequently to the original invention of the feature; and the method was not universally adopted, for in the Tower of London, where there are wide and narrow arches intermixed, the latter are not pointed, though they are as high as the others.

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According to Dr. Moller, the pointed style of Architecture originated in Germany about the end of the

XIIth and beginning of the XIIIth century, probably, from a desire to replace the flat or low-ridged roofs of the former style, by others of considerable elevation, which are better adapted to the climate of that part of Europe from the greater facility with which they suffer the rain and snow to fall from the building. This form of roof, Dr. Moller supposes, would necessarily lead to corresponding alterations in other features of the buildings, in order to produce a harmony in all the parts; hence the walls, the columns, and the towers, were all made more lofty and more slender; the arches assumed a pointed form; and the flat pilaster spreading more outwards was converted into a flying buttress.

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The opinion of Dr. Milner, that the idea of the pointed arch was taken from a view of the intersection of two semicircular arches standing in the same plane, seems extremely reasonable, inasmuch as it makes the former a modification of the other, which its posteriority of date seems to justify; and the change is just what might be supposed to be made by a people acutely anxious to vary the forms and beautify the members of their Ecclesiastical edifices. We find, in the Saxon and Norman-Gothic buildings, that the practice of making arches intersect each other by way of ornament against the walls was common; and as this disposition left a cuspid arch between every two semicircular arches, it is extremely probable that it would occur to some person to perforate the wall under this arch, and thus form a pointed window. The idea being started, the form would be immediately copied for windows, for doorways, and even for arcades. Thus that which was at first, perhaps, only the result of accident, or of a capricious taste, might become the model of an elegant and refined system.

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The opinion of Bishop Warburton on the origin of the pointed Gothic Architecture, though extremely fanciful, must not be omitted in an enumeration of the hypotheses proposed to account for the invention of this singular style. That learned divine supposes that the Goths who overthrew the Roman Empire, having been accustomed to perform their Religious rites in natural caverns, or in dark groves under the interweaving branches of trees, when they became Christians, erected for themselves places of worship in a style of Architecture drawn from the forms of those caverns and groves. These they imitated in stone; the doors or arches which led to their places of worship they decorated with a profusion of foliage and tendrils which, with a sort of negligent wildness, spread over the path. This was either intended to represent the entrance to a cavern, about which are scattered shrubs and wild flowers, or the opening into a wood formed by the opposite trees intertwining with each other. The great entrances to some of our Cathedrals exhibit this in a remarkable manner; in the middle rises a pillar resembling the trunk of a tree, which by an expansion of its branches on each side forms a passage through two arches from which the whole avenue of columns with the ramifications spreading towards each other and along the roof, form a perspective, arresting the attention by its grandeur and beauty.

It cannot be denied that this picture is highly interesting; it is pleasing to deduce a complicated system from one simple idea, particularly when that idea is afforded by Nature herself; and, in this respect, Bishop Warburton's hypothesis has an advantage over that which deduces the Grecian and Roman Architecture from an original hut. But if it be objected to the latter hypothesis, that many intermediate steps must occur between the timber-hut and the Greek Temple, much more numerous must be the steps between the natural grove or cavern and the rich Gothic Cathedral with its pointed arches and spires, complete in all their parts. Again, it may be observed, that the Goths and Vandals, who entered Spain in 409, did not then first adopt the Religion of the ancient inhabitants of the Country, for they were already Christians; and, consequently, were not likely to erect buildings in imitation of the groves consecrated to Deities whose worship they had long before abandoned. And even if such had been the case, the style of Architecture which they invented must have remained concealed from the rest of Europe till the XIIth century, when it was adopted by the Germans, French, and English. But this is quite improbable, and there is reason to believe that the earliest examples of this kind of building occur in the North of Europe, and that these were subsequently copied in Italy and Spain.

Supposed
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the ancient
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The ingenious theory lately proposed by Sir James Hall, in his Work on the *Origin of Gothic Architecture*, presents a close analogy with that in which the Grecian buildings are deduced from a timber cottage, and completes the application of the principle to all the different styles of Architecture in use; it therefore deserves to be here mentioned. This theory is founded on the probable practice of a people who, like our Saxon ancestors, formed the walls of their dwellings by interweaving the small branches of trees with the upright posts in the manner of basket-work; and who may be supposed to have constructed their Religious edifices in the same manner, but with greater taste. Sir James thinks they would plant a number of posts, or trunks of trees, in vertical positions, and in two parallel rows, at certain distances from each other, so as to form on the plan a series of squares or rectangular parallelograms, and together constituting one great rectangular avenue. Surrounding each of these they might also plant vertically a certain number, he supposes eight, of long slender branches of a flexible wood, which being bound to the principal posts at bottom and in some part of their length, would cause it to resemble what is called a clustered column, with its base and capital. The upper parts of these branches, being bent till they met over the middle of the interval between the posts to which they are attached, would form the outline of a groined vault with an arcade on each side; and these arches might be either semicircular or pointed, according to the manner in which the branches were bent; lastly, a pole running down the length of the avenue, and joining the vertices of all the arches which cross the avenue, will represent the ridge of the vault. Sir James supposes the sides and top of this framework to be filled up by branches interwoven, leaving intervals for the windows; and thus the walls and roofs of the primitive Churches to have been formed. By other ingenious dispositions of flexible branches he supposes the different kinds of windows which are found in Gothic Ecclesiastical edifices to be represented; and he considers that all these circumstances were copied in the formation of the first Churches which were built of stone, in the North of Europe.

Plausible as this theory must be admitted to be, it can only be considered as an agreeable sally of the imagination; for though a contemplative mind may discover a conformity of the clustering pillars and diverging ribs of vaults to the framework of a wicker house, yet, as is observed by Dr. Moller, it is by no means certain that this conformity is the result of imitation, seeing that it may arise from other causes, and that it wants, what he considers as the characteristics of originality, *viz.* that it be found in some particular Country, and that it arise from causes depending on the manners and institutions of the inhabitants. An insuperable objection to the theory is, that the pointed arch occurs in buildings which have no other characteristic of the Gothic style; and, on the other hand, nearly all the other characters may be found complete in buildings wherein not a single pointed arch is to be found; some of the Churches in Normandy afford examples of what has been just said.

Supposed origin of the narrow lancet-headed windows.

We have already observed that the long and narrow window which is frequently found in the Churches of the East of Europe might have originated in the difficulty of constructing a lintel or arch to support itself in the wall of an edifice which is circular on the plan; and it is likely that the resemblance of such windows to the form of an arrow, might have inspired some builder with the idea of changing the semicircular head which they had at first for one terminating in a point like a lancet or arrow-head. This is a form which we find such windows to have in some of the oldest Churches of Europe; and it is easy to conceive that when they were employed in walls with plane surfaces, two or more of them would be placed side by side, in order to gain more light for the interior of the building; and to make an appropriate finish above them, the mouldings on each side would be continued in curves of similar form to meet in a point above the middle of the window. The space between the exterior arch and the sides of the others would require some ornament, and the perforations in the forms of trefoils, quatrefoils, &c. which are generally employed, accord well with such situations; and the prolongations upward of the mouldings about the lancet-headed curves would naturally lead to the tracery-work, which about the same time became a distinguishing feature of this kind of Architecture.

Forms of Gothic edifices determined by a triangulation.

The triangular form of the vertical section of a Gothic Cathedral has given rise to an opinion that the Architects of those edifices determined the positions of their principal points, on the plan, elevation, and section, by the description of a series of equilateral triangles with the vertices of which those points were in coincidence. The first person who started this idea was Cæsar Cæsarianus, an Italian Architect, who shows, in his edition of Vitruvius, that the principle holds good in the Cathedral of Milan; and Mr. J. S. Hawkins has since endeavoured to show that it is applicable to the Cathedrals of our own Country. The opinion may not be altogether without foundation, for such general methods were, undoubtedly, employed in the works of the Greeks and Romans. Among those people the length of a Temple was made to depend on the number of columns in front, and the length, breadth, and height ultimately depended upon the diameter of the columns; moreover, something like the system of triangles occurs in the rules given by Vitruvius for determining, on the plan, the disposition of the parts of the Greek and Roman Theatres; and there is reason to believe that the Gothic Architects had some established rules, which are now lost, for the construction of their Ecclesiastical buildings. No rules, however, have yet been discovered so general as those of the more ancient Architecture, which were applicable to every edifice of the same kind; an advantage arising from the greater simplicity of its buildings, both in the plan and elevation. In the Gothic Architecture, if the system of triangles is really that by which the artists were guided, a different triangulation seems necessary for every different edifice.

In applying this principle to the transverse section of Salisbury Cathedral, we find that the vertices of the vaults of the aisles are in a horizontal plane passing through that of an equilateral triangle, the base of which is a line on the pavement equal to the breadth of the nave and the two side columns; and the summit of the vault of the nave is at the vertex of an equilateral triangle, the base of which is the interval between the centres of the aisles taken in a horizontal plane passing through the tops of the capitals of the columns on each side of the nave. In York Cathedral, the tops of the vaults of the side aisles are in a horizontal plane passing through the vertex of an equilateral triangle, the base of which is on the pavement, and equal to the distance between the centres of the columns which support the longitudinal arcades; and the top of the vault of the nave is at the vertex of an equilateral triangle, the base of which is on the pavement, and equal to the whole breadth of the nave and aisles, including the thickness of the walls. The vertices of the vaults, both of the nave and aisles, in Lincoln Cathedral, are determined nearly in the same manner as in the last example; and it may be added, that the springings of the vault of the nave are in a horizontal plane passing through the vertex of an equilateral triangle, the base of which is the distance of the centres of the side aisles from each other; and those of the vaults in the aisles are in a plane passing through the vertex of an equilateral triangle, the base of which is equal to twice the breadth of the aisle. But the variations found in our principal Cathedrals leave little chance of discovering any general system for their construction, and it is rather probable that the artists of the Gothic edifices did not bind themselves to any constant rules in the works they executed.

Supposed origin of Freemasonry.

During that period in which the building of Churches was constantly occurring, and every effort was made to execute them in the most perfect manner, persons would be wanted who, having applied themselves exclusively to their erection, had acquired a certain facility in it. Just such a class of men was found in the Freemasons of those times. These were originally, it is supposed, refugees from Greece, Italy, Germany, and France, who were skilled in the Art of Building, and who formed themselves into a fraternity for their general benefit. They are said to have travelled from place to place, and to have engaged themselves to carry on the works which the Architects, that is to say, the Ecclesiastics, had designed. There does not seem, however, to be any foundation for the opinion that they were invested with corporate powers by the Pope, in the XIIth or XIIIth century, as has been supposed; and it is observed by Mr. Britton, that they were not known to exist as a distinct body till the reign of Henry VI., in whose third year, that is, in 1424, an Act of Parliament forbade them to assemble in general Chapters. Persons admitted into the Society were instructed in the mysteries of the Art, and were bound not to divulge its secrets to the uninitiated. Near the building which they had undertaken they formed an encampment of huts, in which they resided, and they were subject to a regular Government of their own. One man, who acted as a Surveyor, was responsible for the conduct of the party employed in the work, and every tenth man was a Warden: and if any Member conducted himself improperly, he was expelled from the

Society. A class, like this, of men jealous of the reputation of their Society, must, by the mutual emulation subsisting among its members, have brought the practice of masonry to considerable perfection; it is not wonderful, therefore, that we find the accuracy of the work performed in those Ages equal to any thing that could be executed by the best workmen of the present day. And we may, perhaps, attribute to the members of that Society the invention of many ornaments, if not of some of the principal features in the buildings of those times.

CHAPTER VII.

Characteristics of the Pointed Architecture in different Ages.

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About the end of the XIIth and beginning of the XIIIth century, that which is called the *Pointed Style* of Gothic Architecture was introduced into the principal Ecclesiastical buildings of Europe, and gradually superseded the more ancient modes exhibited in the Saxon and Norman buildings. The new style is characterised, in a general way, by its high ridged roofs, its pyramidal towers, and the pointed form of its arches and vaults, all which features give to the buildings of that day an air of lightness and magnificence, forming a powerful contrast to the low and massive works of the preceding Age. Efforts have been made to prove that the acute features, as they are called, are of earlier date in the Continental Churches than in those of England, but the arguments only prove our ignorance of the precise time of their first occurring in the edifices of any Country. In fact, the great intercourse subsisting among the Prelates of the North of Europe, during those Ages in which Church-building was so general, would, naturally, lead to the adoption, in one Country, of any style which had been invented in another. Hence it might be expected that there should be, almost at the same time, an uniformity in the characters of the Churches which it was the chief business of those Prelates to build or adorn.

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Besides the edifices formerly mentioned, in which the new style of Architecture seems to have been first introduced, Germany has produced many examples which will for Ages remain as proofs of the great talents of her artists in raising magnificent piles for the service of Religion. The Church of the Knights of the Teutonic Order at Marburg, which was begun in 1235, is in this style, and besides being executed in a most skilful manner, is distinguished by great simplicity and elegance. The Cathedral of Cologne, which was begun in 1248; that of Strasburg, in 1274; that of St. Stephen, at Vienna; and the High Church, at Ulm, are also structures in which the same style seems to have been carried to perfection; and some of these possess even greater richness of character than the buildings executed, in England, in the time of the most florid state of Gothic Architecture in this Country. But it seems that, in Germany, the Art declined during the XIVth century; the buildings of that period wanting the regularity of form which constitutes the merit of those which are more ancient. Profusion of heavy and ill-executed sculpture also was resorted to, in order to produce a striking effect, for some time previous to the introduction of the revived Italian style, in the North of Europe.

France,

The Cathedrals of France, the construction or completion of which is referred to the XIIIth and beginning of the XIVth centuries, closely resemble, and equal, if they do not exceed, in richness of decoration, the contemporary Churches of England; and, though, as is observed by Dr. Milner, the most magnificent edifices in the North of France, the Cathedrals of Notre Dame, at Paris and Rouen, and those at Amiens and Beauvais, for example, are by the French themselves attributed to English artists, yet the members of these buildings are distinguished by certain peculiarities which show them to have an independent origin; and the taste which dictated them may, with great probability, be ascribed to natives of the Country.

The wars with the English, and internal commotions, prevented the Architecture of France from making progress, during the two following centuries, corresponding with that which it had made before. And, in the XVIth century, the Gothic Architecture, as well in France as in Germany, was abandoned to make way for the style which had then recently been formed in Italy from the study of the remains of ancient Rome.

and England.

In England, notwithstanding the long period during which the Country was involved in a Civil war, the taste for Ecclesiastical Architecture maintained its ground, and the works executed during the XIIIth, XIVth, and XVth centuries may vie with most of those on the Continent at the same periods. But the cessation of those wars near the end of the XVth century, and the wealth which the nation began then to acquire by commerce, enabled the Sovereign, and the Prelates, to put in execution some of the richest designs which invention could furnish; and just before the revolution in taste which brought on the Italian style, the Gothic Architecture, like the expiring flame of a lamp, shone for a short period with redoubled lustre. It was at this time that the exuberantly ornamented Chapels at Westminster, Windsor, Cambridge, and other parts of England were erected; and these, by the care taken to repair them in their original style, will, probably, for Ages remain among the most perfect monuments of a system of Architecture which seems particularly adapted to buildings consecrated to the Christian Religion.

Changes introduced in the Gothic Architecture together with the pointed arch.

The disposition of the Cathedrals and Churches erected in England, subsequently to the abandonment of the Norman style of Architecture, was the same as before, with respect to the plan; that is, the cruciform style was still retained, with only such modifications as two transverse rectangles instead of one, as in the Cathedral of Salisbury, or two chancels, one at each end of the building, as in some of the German Churches. But the great change that took place in the form of the arch seems to have brought with it a corresponding change in every vertical feature; the exterior of the roofs, the vaults, the towers and windows were made more lofty than before, and even the ornamental objects were made to assume a pyramidal form. The pillars and ribs of arches were reduced in breadth by deeply-cut mouldings and ornamental sculpture, till the greatest degree of lightness consistent with stability was attained. A considerable change took place, also, in the quantity and quality of the sculpture; which then became more abundant and greatly improved.

Uncertainty of the period in which particular style prevailed.

It is impossible to express accurately the peculiarities of style existing at different periods in the Gothic buildings, on account of the great liberties the artists allowed themselves of blending the style of one period with that of another; this is in nothing more evident than in the forms of the arches. It is understood, for example, that in the first Age of the pointed arch; that is, in the XIIIth century, it was of the lancet form, the radius of each curved side being greater than the span of the arch. In the XIVth century, the pointed arch is supposed to have had its vertex lowered, as if the curves were described on the sides of an equilateral triangle, the radius of the curve being equal to the span. After this period the vertex became still lower, the radius being little more than half the span of the arch: finally, a little previous to the suspension of the Gothic style of Architecture, the arch assumed the figure of two hyperbolic branches, of considerable curvature at the springing courses, and nearly rectilinear to a certain distance on each side of the vertex, where the branches met at a very obtuse angle. But, though this seems to have been the general progress of taste with respect to the form of the arch, yet we often find in the more ancient buildings, arches much lower than in those that are less so, and equally great discrepancies may be observed in every other feature; all that is meant, therefore, by assigning a particular period to any one character is, that the generality of the buildings of that period were conformable to it, while the exceptions are numerous. And it is easy to conceive that, in the absence of Historical documents, the indications of antiquity drawn from the forms of the members of a Gothic edifice, are as uncertain as those drawn from the proportions of the parts of a Grecian Temple.

Examples of the first deviations from the Norman style in England.

The Norman style of building began to be modified before the middle of the XIIth century; but, as might be expected, the works erected between the time of the first departure from one method and the complete establishment of another, partook in some measure of the characteristics of both. In fact, the Churches which were built about the time of the first introduction of the pointed arch, contain such a mixture of styles as indicates an entire ignorance or disregard of the principles of good taste.

According to Dr. Milner, the Church of St. Cross, near Winchester, was built in the beginning of the XIIth century, and, if so, it must have been one of the first in which there is a departure from the Norman style of building; but the alterations subsequently made have introduced into it every species of Gothic Architecture. The columns which divide the nave and aisles are massive cylinders or prisms, the heights of which, including the bases and capitals, are equal to about three times their diameter; and from the capitals of these spring cuspid arches which differ little from semicircles. About the middle tier of windows in the choir, are semicircular or flat segmental arches springing from piers and intersecting each other; and, within the intersections, the wall is cut away to form pointed arches crowning the apertures of the windows; while, in the Eastern wall, some of the windows have exactly semicircular heads. The mouldings and ornaments about the windows are of the Norman or Saxon kind.

To the same century are referred the Churches of Barfreston, in Kent, and of Buildwas Abbey, in Shropshire, both of which appear to exhibit the earliest specimens of pointed arches. In the walls of the first are cut lancet-headed recesses, and the arcades in the nave of the other are of the pointed kind, springing from cylindrical pillars, while the upper windows have semicircular heads. Both Churches, also, contain some of the members of a later style which may have been introduced at the repairs made in subsequent periods.

The same mixture of styles prevails in the choir of Canterbury Cathedral, Malmsbury Abbey Church, in Wiltshire; Rumsey Church, in Hampshire; the Temple Church, in London; and many others, which belong to this century. The Cathedral at York is also one of the first grand edifices in which the pointed arch was used, but the part above ground having subsequently undergone many alterations, the original style is hardly perceptible: much of it, however, remains in the crypt, in which place the arches are slightly pointed, and spring from short round pillars, the capitals of which are adorned with animals and foliage. Rumsey Church presents some remarkable peculiarities, which are worthy of being mentioned, though they probably belong to the Norman style. On the Northern side of the chancel, the lower and second tiers of arches are semicircular-headed, but the apertures of the second tier are divided into two equal parts by a single column, upon the capital of which rest the adjacent extremities of the two interior arches, which are also semicircular, and cover the aperture on each side. On the capital of this middle column rests a smaller one, which seems to support the crown of the exterior arch. Above this arcade is an arched passage, formed in the thickness of the wall, and in the direction of its length, with an aperture towards the interior of the Church; the aperture is divided into three parts by short columns, above the capitals of which are rectangular piers, nearly equal in height to half the height of the column, and serving to support the semicircular arches over the intervals of the columns. The employment of a column to support the crown of an arch, occurs, to our knowledge, only in some of the Norman buildings, and it indicates either an absurd taste in ornamental Architecture, or a want of confidence in the stability of that feature.

Examples of lancet-headed arches.

A fine specimen of the style prevailing in the latter end of the XIIth and beginning of the XIIIth centuries, is the face of the Southern transept of Beverley Minster, in Yorkshire, which, fortunately, remains in excellent preservation. In the centre is a doorway, divided into two parts by a single pillar, supporting the adjacent extremities of two lancet-headed arches which cover the apertures; both these arches are included within one of a semicircular form, the mouldings of which spring from an assemblage of clustered columns on each side; above this are two tiers of lancet-headed arches, three in each tier, and at the base of the gable, or pediment, is a circular window with mullions radiating from a rose in the centre, and forming what is called the Catherine-wheel window. In each of the lateral divisions of this face is also a lancet-headed window, over which is a circular panel containing four star-formed perforations. The great pointed window, the tiers of panelling, and the ornamental foliage at the Eastern end are, probably, of later date.

The great Western window of the Church at Wells, is similar to those over the doorway at Beverley, for it is composed of three lancet-shaped divisions separated, however, not by mullions, but by piers of masonry, nearly equal in breadth to the apertures themselves. The present work is said to have been a rebuilding of the original, about the year 1239, and the simplicity of the groining in its nave and transept, shows that it belongs to the first period of the Pointed Style of Architecture.

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From these examples we may conclude, that the Gothic edifices of the XIIth century presented few deviations from the Norman style; the columns may be considered still as consisting, generally, of a single cylindrical shaft; the great arcades, if not semicircular, were formed of two segments differing but little from quadrants, so that the arch had the appearance of being very slighty pointed. The heads of the windows and smaller apertures, on the contrary, were formed of two arcs of circles making a very acute angle at the vertex, the radii of the sides being equal to two and even three times the span of the aperture; and the Norman mouldings and zig-zags were still retained about the arches. The Catherine-wheel window seems to have been introduced; and, in one of the façades at the extremity of the building, three lancet-headed windows were placed at small distances from each other. In the great Cathedrals, where the exterior of the wall is ornamented, the ranges of arches, simply pointed and resting on short pillars, appear to have been employed in the latter part of this century; and it is probable enough that some of the more complex forms of arches were invented during the same period, but their use was not sufficiently general, or the dates of their construction are not sufficiently certain to allow us to consider them as characteristic features of the buildings in that Age.

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Salisbury Cathedral, which was almost entirely built in the XIIIth century, is considered as exhibiting the most complete assemblage of the parts belonging to that period; and though individual examples of some of the members often occur in edifices of an earlier time, yet it is from this period that we are to date the general employment of the features, collectively, in Ecclesiastical buildings. In the screen at the Eastern end of the choir of that Cathedral are two clustered columns, consisting each of four shafts united together on a common octagonal plinth, and supporting a pointed arch, the sides of which are formed on those of a rectilinear triangle nearly equilateral. On each side of this, in the same screen, is an acutely-pointed arch, one side of which rests on a column consisting of one stout, cylindrical shaft with four slender ones attached to its surface. A more complex species of clustered column also appears in the nave and transept of this Cathedral; it consists of many slender shafts united in one body like a bundle of rods, to which it has often been compared, and though it may have occasionally occurred before, it became from this time a constant feature in Gothic edifices. The shafts were either plain or divided into two or more parts by small fillets or astragals of stone surrounding the whole pillar, and the capitals, bases, and plinths were commonly octangular.

Columns grouped about a central pillar in the manner just mentioned are usually considered as essentially distinct from those of the Saxon or Norman kind; but this is not a correct opinion, for they occur in several of the old Churches executed according to those styles; for example, in the Churches of St. Etienne and of St. Hildebert, at Gournay, in Normandy, and the Cathedral of Durham in our own Country. It may be remarked that similar groups are found in the Church of St. Catherine at Oppenheim, the construction of which is referred to about the same period as that of Salisbury Cathedral.

In the buildings of this century the arches, which at first had been of the acutely pointed or lancet form, were subsequently made with radii equal to about four-fifths of the span of the arch; the intrados of each branch was generally a continuous curve, but often it was cut into a series of segments of small circles meeting each other and forming rentrant cusps towards the centre of the arch; and these cusps sometimes, as at the entrance of the Chapter-house, at Salisbury, ended in sculptured leaves. The mouldings about the arches of the naves are made to consist of assemblages of slender, curvilinear reeds with concave grooves between them, and above the extrados is a moulding, not resting on the capitals of the columns, but terminating in a sculptured head projecting from the spandril above the capital. Such are the arches of Rumsey Church, in Hants, and of Salisbury Cathedral; the Norman ornaments upon the archivolts were generally abandoned, except the zig-zag, which in some examples was retained; and in the latter part of the century, a series of small crosses, or, as they are called, dog's-tooth ornaments, appears along the mouldings of the arches, as in those of Litchfield Cathedral. This ornament was, however, employed on the Continent at an earlier date, for it occurs in the Abbey Church of the Holy Trinity, at Caen, in Normandy, which having only semicircular arches was, most probably, built before the invention of the pointed style.

The arcades of the triforia are composed of one exterior pointed arch resting on short columns grouped together over those in the lower arcades; within it are two pointed arches, the adjacent extremities of which rest upon a short, clustered column over the apex of the arch below: and within each of these are two smaller pointed arches, the extremities of which rest upon a single column in the middle. The soffit of each of these four small arches is cut by five segments of circles forming rentrant cusps in the manner above mentioned: and in the spandril between each of the two smaller, and also between the two greater arches under the principal one is an aperture formed by ten intersecting segments within the circumference of an exterior circle.

Stone-vaultings and high roofs of the XIIIth century.

In this century, and, perhaps, at a period somewhat earlier, the timbers of the roof, which had been formerly exposed to view from the interior of the building, were concealed by a groined vaulting of stone which was formed several feet below them, so as to leave a void between the extrados of the vault and the outward covering of the roof, a construction to which the name of *chare-roof* was given. The ribs at the edges of the groined vault of the nave were ornamented with mouldings, and, at first, made to spring from the pillars supporting the arcades; but, subsequently, some were made to spring from corbels between the windows in the side walls, or from the capitals of small columns with single or triple shafts resting upon heads which project from the wall between the exterior arches of the triforia. Between the ribs at the angles of the groins, others were formed on the plane face of the wall, and all extended to a sort of spine coinciding with the crown of the longitudinal vault of the nave; the profile of the spine was similar to that of the ribs, and the intersections were marked by knots of foliage or flowers.

The profile of the stone-vaults having, like the arches, an acutely-pointed form, the artists were obliged to give to the external roof that great height which forms one distinguishing feature in the buildings of this and the succeeding Ages. Hitherto the roofs had been low pitched, resembling those of the Greek and Roman edifices, but, from this time, it became common to make the inclinations of the sides to the horizon not less than sixty degrees, so that the gables or pediments have the appearance of equilateral triangles. Wooden spires of a pyramidal form and covered with lead, had, before this century, been common in the Norman Churches; but they began now to be formed of stone, on polygonal bases, and to be highly ornamented. The buttresses, which had hitherto terminated at the top of the side walls, were at this time raised above it; and at the upper extremity was formed either a pinnacle or a sort of pediment. Flying buttresses, consisting of simple arched ribs, were formed above the roofs of the side aisles, in order to resist the lateral pressure of the central roof against the walls over the arcades of the nave.

Windows of the same period.

In the beginning of this century the pointed windows of Churches became broader than before; the aperture was divided into two parts by a vertical mullion, and each division or light was covered by a pointed arch-head of the lancet form, as had previously been the case with the semicircular-headed windows in the Norman Churches. In the spandril between the exterior curve and the heads of the two lights was frequently formed an aperture consisting of three, four, or more segments of circles intersecting each other about a centre, so as to produce rentrant cusps and form a trefoil, quatrefoil, &c. aperture: such are the windows in the side walls of Westminster Abbey, which were probably executed in the time of Henry III.

At the Western extremity of Rumsey Church is a great window divided into three parts, nearly equal to each other by two vertical mullions, the interior faces of which are ornamented with slender columns in clusters, and each aperture is covered by an arch of the lancet form. But in the same century some of the greater windows were crowned by pointed arches nearly equilateral and divided by one principal mullion, ornamented with clustered columns, into two parts with pointed arch-heads similar to that of the whole window; and each of these was subdivided, in a similar way, into two others. The spandril between the secondary and tertiary arches was occupied by a quatrefoil aperture circumscribed by a circle, and that within the principal and between the secondary arches by an octofoil aperture, circumscribed also by a circle: such are the windows of the Chapter-house, at Salisbury. This, probably, preceded the method of dividing the windows by upright mullions, branching off at top and forming a tracery-work by their intersections, a method which, however, occurs in works executed nearly at the same period. In Litchfield Cathedral, and in the Western aisle of the Northern transept of Westminster Abbey are windows formed by describing arcs on the three sides of an equilateral triangle, with the angular points as centres; the interior is occupied either by tracery or by three circles touching each other and the sides of the window. Such windows were sometimes formed in the clere story; but generally the windows in that part of the building are divided by clustered shafts, and the apertures terminate in lancet heads.

The smaller windows of this century seem very generally to have had trefoil heads, but the middle segment in the intrados was formed with a cusp at the vertex. The ornamental ranges of arches on the exterior and interior faces of walls were also of similar forms, and were supported, as before, by small columns.

On the exterior of the building, pediments were, at this time, formed above the extradosses of arches and windows, and terminated at each foot in some figure which projected from the face of the wall; these pediments were sometimes rectilinear, but generally curvilinear, at first concentric with the sides of the arch itself, but about the latter part of the century they became curves of contrary flexure terminating in points and ornamented. The canopies in the walls of Churches, which were before plain, were ornamented in a style corresponding with that of the windows, and were occupied by statues.

Form of pillars in the Cathedrals of the XIVth century.

During the XIVth century the style of Architecture became more light and elegant than before, and may be considered as having attained the state of its greatest purity. The clustered columns now consisted of a greater number of shafts, and formed a mass the plan of which might be circumscribed by a rhombus, so situated that lines joining the opposite angles are respectively parallel and perpendicular to the length of the building. The four principal pillars which support the central tower are much larger than the others, and are carried as high as the top of the triforia; that is from five to seven times the greater diameter of the clustered pillar. At each angle of the cluster are generally three columns united in one, and between every two such united columns are two or more slender ones, all attached to the main body of the pillar. Each column in the cluster has a plinth or, rather, a low pedestal of a polygonal or circular form on the plan, and above this is a torus and fillet; the plinths and mouldings respectively, by uniting, form a general base for the whole cluster. In the same manner, each column in the cluster has its own capital, formed of mouldings, flowers, or foliage, with a circular or polygonal abacus above, and these are united in one general capital for the whole pillar. The columns or stems at the angles are generally uninterrupted from the base to the capital, but those intermediate are broken into three or more equal parts by astragals and fillets. The pillars of the side arches in the nave are about one-third of the height of those under the central tower, and are formed in a similar, though not always in the same manner.

Arches and vaults of the same period.

These arches are of the pointed form and nearly equilateral; each side is formed as if composed of a number of circular mouldings springing from the capitals of the stems which constitute the clustered column. Above the summits of these arches a small horizontal moulding runs quite through the length of the building; over this is the triforium or second arcade, consisting of a series of pointed arches like those before described, and above these is a second horizontal moulding, either plain or ornamented. Between every two arches in the nave, and every pair in the triforium is a slender column, either single or triple, rising from the pavement up to the second horizontal moulding, where it terminates in a small capital, from which spring the ribs in the groined-work of the vault. The height of the lower arcade is generally about five-eighths of the height from the pavement to the rise of the vault, and that of the upper arcade is about equal to the remaining three-eighths. The spandrils between the curves of the arcades and the horizontal mouldings above are generally plain, but sometimes filled with trellis-work, as in Westminster Abbey. In some cases there are two tiers of galleries over the lower arcade, as in the transepts of York Cathedral; but sometimes, as in the nave of the same Cathedral, instead of galleries the whole of the side walls above the lower arcade is occupied by large windows. The most common case, however, is that in which there is one triforium, and above it, within the lateral vaults of the groined-work, a tier of clerestorial windows.

The tracery in the ceiling of the body of the building became, in this century, more intricate than in the former; for the ridges of the lateral vaults not being so high as that of the longitudinal vault, the ribs at the angles of the groins frequently cross each other and also the intermediate ribs, and thus form many compartments, at all the angles of which are knots of flowers or foliage. This kind of tracery is exhibited in the vault of the nave of Winchester Cathedral; and the faces of the vaults between the ribs are sometimes ornamented with trellis-work, as in Lincoln Cathedral.

he towers.

The central tower was a rectangular building terminating with battlements, and containing windows on each side; in some examples the angles of the tower were furnished with pinnacles enriched with sculpture, and in others the tower was crowned by a lofty pyramidal spire. The two towers, which were placed one on each side of the Western front of the nave, were similar to that over the centre of the building; that is, they either terminated in battlements and pinnacles or were surmounted by spires. In some cases we find the angles of the towers plain, in others they are strengthened by buttresses, plain or ornamented, and either rectangular or polygonal on the plan; the pinnacles are usually placed only on the summits of the buttresses, but occasionally one is also placed over the centre of each face of the tower, and all are of a conical or pyramidal form. The towers are usually divided into two or more parts by horizontal mouldings; and between these are either windows, or niches and canopies containing statues, or ranges of arches standing on small pillars, like those in the Pisan edifices; only the arches are either simply cuspid, or consist of a trefoil formed by three arcs of circles blending with each other in a line of contrary flexure. The battlements of the towers or of the general body of the building are sometimes plain, at other times formed of open-work; and the exterior of the walls, gables, and buttresses is ornamented with canopies, ranges of ornamental arcades on slender pillars, and sometimes partly with trellis-work.

indows.

The Western façade of the building was occupied by a window placed over the doorway, sometimes equal in breadth to the whole of the nave and reaching to the top of the vault. This and the other windows were divided by mullions and transoms, the former generally dividing into ramifications near the upper extremity of the window, and by their intersections producing a tracery representing loops and foliage, as in the Cathedrals of York and Carlisle. The rectangular compartments of the windows were filled with painted glass representing Apostles, Saints, or Kings. The arched heads of most of the windows of this time were higher than the equilateral kind; and above the extrados, on the exterior of the building, were pediments in the form of curves of contrary flexure, which, as well as the sloping sides of the gables, pinnacles, and buttresses, were profusely ornamented with crockets and crowned by finials.

Occasionally, the mullions proceeded in rectilinear directions to the head of the window, and the walls and buttresses were ornamented with panels standing immediately over each other, so as to cause a system of vertical lines to appear to predominate on the exterior of the edifice; and hence Mr. Rickman has, with some propriety, applied the denomination of the *Perpendicular Style* to that which prevailed in the latter part of this, and the beginning of the following century.

About the same time the circular window, usually placed at one or both extremities of the transept, was increased in size and divided into compartments by radiating pillars and concentric circles, as in Westminster Abbey, or by a tracery representing loops and foliage arising from the intersections of branching mullions, as in the Cathedrals of Winchester and Litchfield. An elegant circular window of a similar kind, and probably of the same period, remains in each gable of the Church of Buildwas Abbey, in Shropshire.

Besides the buildings we have mentioned, the Conventual Church of St. Augustine, at Bristol, and St. Stephen's Chapel, at Westminster, now the House of Commons, are to be considered as among the best specimens of the Architecture of this Age.

Satirical sculpture.

In works erected during this century, we find the first examples of that sculpture which disgraces many of our noblest buildings. Fools, mountebanks, and satirical representations of Monks are the principal subjects on which this depraved taste was exercised; and sacred edifices, where every circumstance should inspire serious sentiments, were the places chosen to exhibit them. According to Mr. Douce, the figures may have been intended to cast ridicule on certain classes of men, or to express the mummeries practised at the Feast of Fools. The same kind of sculpture was, at a later period, employed on the under sides of the *misereres* or *turning-seats* in some of our Cathedrals.

General characteristics of the Architecture of the XVth century.

From the end of the XIVth to the beginning of the XVIth century another change took place in the style of Architecture. The arches of the arcades, doors, and windows became much lower than before; the upper part of each side was nearly rectilinear, and the two formed a very obtuse angle at the vertex. This, which was called the *Tudor arch*, though generally, was not universally employed, for the equilateral form is also to be seen in buildings of the same Age.

The vaulting in the roof, like the arch which served for its model, became nearly flat about the vertex, the angles of the groins being rounded, the spandrils assumed the form of an inverted bell either entirely or in part, and the upper portion of the surface marked upon the ceiling the whole or a segment of a circle. The spandril itself was covered by numerous small ribs which branched from the capitals of the columns, and gave to its surface the appearance of a fan; and between those spandrils, others, consisting of masses of stone, each weighing more than a ton, in the shape of inverted bells, and ornamented with fanwork, were pendent from the vault. At the intersections of the ribs of the fanwork, armorial shields were sculptured, and the lower extremities of the pendents were ornamented with foliage. The exterior covering of the roof, which before had great elevation, was now again reduced very low in order to correspond with the form of the vaulted ceiling.

The vertical mullions of the windows proceeded from the sill quite to the top of the arched head, and were crossed by transoms frequently ornamented with small battlements. Over the doors and windows was generally a horizontal, rectilinear moulding, which terminated on the vertical sides produced, so that the aperture of the door or window seemed enclosed in a rectangular recess. A horizontal label was placed a little above the top of the recess, and a branch at right angles to it extended a little way down each side, where it terminated either in a lozenge-formed ornament, or in a short branch parallel to the upper part of the moulding.

In the buildings of this Age, the windows occupy so great a portion of the walls that, as Dr. Milner observes, the whole Church has the appearance of a glass-lantern rather than a substantial building.

The vertical buttresses of this Age are of a polygonal form on the plan; they rise considerably above the roof of the aisles, and their faces are highly ornamented with panels, battlements, and elegant projecting canopies; the sides of the flying buttresses also are ornamented with tasteful perforations, and their extradosses with crockets or creeping animals. On the tops of the vertical buttresses are pinnacles, the profile of which is bounded by curves of contrary flexure meeting in a point at the top; the faces of these are ornamented with a sort of network, their ridges with crockets, and their apices with elegant finials; and, in fact, every member of the building received in this century the highest degree of enrichment of which it seems capable. The principal examples of this florid style are Henry the VIIth's Chapel, at Westminster, and King's College Chapel, at Cambridge; and it may be easily imagined that this elaborate workmanship could only be bestowed upon the smaller kind of Ecclesiastical edifices.

of the XVIth century.

At the dissolution of the Monasteries in the XVIth century, the last change took place in Gothic Architecture; the works of Cardinal Wolsey at Oxford and at Hampton Court are examples of the style, which then became common in Ecclesiastical and Palatial buildings, and even in private dwellings.

Instead of that exuberance of ornament which a short time before covered every part of the edifice, the utmost plainness prevailed. This was a necessary consequence of the almost general employment of brick and rubble stone in building, in place of the masonry which permitted a full display of the powers of the chisel. An air of meanness reigns in all the works of this period, because the rude materials of which they are constructed are incompatible with the graces of ornament. The doorways were still crowned by an obtusely-pointed arch, but the windows were rectangular and divided by plain mullions and transoms; small and unadorned arched heads were, however, still retained over the lights or subdivisions of the windows. As if to compensate for the plainness of the exterior, the interior of the Palatial edifices exhibited the highest luxury of sculpture in the marble which surrounded the fire-places and in the wood-work of the apartments.

Timber-roofs, which had before been employed only occasionally for covering great Halls like that at Westminster, became common in the Churches and mansions of this period, and superseded the stone-vaultings of the former Age.

The Architecture of the Churches of France and Germany experienced changes nearly corresponding with that of the Churches in England in the different periods, till the invention of the Tudor style, which seems to be peculiar to ourselves, for no examples of it are to be found in the Churches of the Continent. Previously to that time, whatever may be the differences in the minor parts of Ecclesiastical edifices, their general features either indicate a parallelism in the progress of ideas, or that the artists in one Country adopted almost immediately the variations introduced by those of another.

It is a little remarkable that though the Tudor Architecture was never adopted on the Continent, yet, in the city of Rhodes, the ancient Church and the buildings in the street of the Knights, which cannot be supposed to have been erected at a later period than the end of the XVth century, have windows with obtusely-pointed arches and horizontal labels over them, like those in the nearly contemporary edifices of England: a circumstance which can only be accounted for by considering them to be works executed under the influence of the English Knights, who, before the Reformation of Religion, formed part of the Order then occupying that island.

CHAPTER VIII.

Detailed Description of the component Parts of Gothic Ecclesiastical Edifices.

The general forms of the members which enter into the composition of Gothic edifices have been mentioned in the preceding Chapters, but as it was not convenient then to describe them so much in detail as is necessary in order to afford a sufficient knowledge of their character, we purpose now to do so; and though the great variations found in the different examples, and even in the same building, seem to render hopeless the effort to reduce the Gothic Architecture to general rules, yet a knowledge of the dimensions and proportions adopted in the members of some of the principal edifices, will be of great service in fixing our ideas of the practice of artists in the Middle Ages.

Clustered columns.

Columns with double shafts were employed by the Roman artists in the later period of the Empire, since they occur in some of the Syrian buildings, and possibly there might have been others of a more complex character then existing though since destroyed; but it was not till the XIIth century that the clustered column became general, and assumed the various forms which we are now to describe. At first the central part of the column was circular or elliptical; four slender shafts were applied to the circumference at the extremities of two diameters, which were respectively parallel and perpendicular to the length of the building, and each shaft projected from the central part as much as half or three-quarters of its diameter. Such are the forms of some of the columns of Salisbury Cathedral, and in that building the longest diameter of the cluster is 4.65 feet; the height, including the base and capital, is 25 feet; and the breadth of the aperture of the arch between two columns is 17 feet: consequently the proportion between the diameter of the column and its height is as 1 to 5.4, and the intercolumniation is equal to 3.7 diameters. The heights of the systems of mouldings forming the base and capital are equal to a diameter of one of the attached shafts.

In the nave and choir of York Cathedral, the central part of the cluster is a square each side of which is about 4 feet long; at each angle is a three-quarter column 1.42 feet diameter, and between every two of these, on each side of the square, are two smaller shafts of unequal diameter with small intervals between them. The breadth of the whole cluster diagonally is 8 feet, the height of the shafts at each of those angles from whence the arcades spring is 29 feet, and the breadth of the archway is 19 feet: consequently the proportion between the diameter and height of the column is as

1 to 3.62, and the intercolumniation is equal to 2.37 diameters. The bases of the columns are of the Attic kind standing on octagonal plinths, which are 3.25 feet high, and are divided into two parts by a horizontal moulding; and the capitals are ornamented with foliage. The three shafts at the angle next to the middle of the nave proceed uninterruptedly to the top of the side walls, and support the ribs of the groined vaulting.

The great columns which support the central tower form an irregular rhombus, on the plan, with reentrant angles on two of the sides. In these also, there is one great shaft at each of the four angles, and the intervals between them are occupied by many smaller ones. But the plans of some of the clusters in the transept are nearly circular, and about 4.75 feet diameter; at the extremities of two diameters which cross each other at right angles, is a triple shaft with a vertical fillet or moulding on the face of each; between these is a single shaft with a similar fillet in front; and in each of the intervals is a vertical channel formed in the body of the pillar, and containing a small shaft completely detached from the pillar, except at the base and capital, where it is connected with the general plinth and capital of the cluster.

In Lincoln Cathedral some of the small clustered columns consist of eight shafts disposed about the circumference of a circle; the outline of the plan of each shaft has the appearance of two arcs of circles forming a cusp in front, and the bases, plinths, and capitals are of similar forms. Some of the columns in the nave of this Cathedral resemble those in the nave of York, but the angular shafts are detached from the body of the column, and stand in semicircular channels. There are others in the same line, having eight three-quarter columns about the circumference, with a vertical fillet or bead in front of each, and a semicircular channel or fluting between every two. The shafts at the angles of the cluster are larger than the others, and their heights are equal to from thirty-six to forty times their diameters.

But, in Westminster Abbey Church, the interval between every two of the four secondary shafts is occupied by two smaller ones which are in contact with each other; the diameter of the whole is 5 feet; the height, including the base and capital, is 31 feet; and the intercolumniation is 14 feet; the height of these shafts is divided into three equal parts by fillets, which, on some of the pillars, surround every shaft of the cluster, but, on others, appear only on the four secondary shafts. The capitals are circular or octagonal, and are without sculpture, and the bases stand on high plinths.

At a later period, the clustered columns assumed a still more complicated character: the intervals of every two of the four secondary shafts being occupied rather by vertical mouldings than columns; the plan presenting a succession of salient and reentrant curves, some of them simple, others forming cusps, consisting either of two segments of circles, or two curves of contrary flexure. Such are the columns in the nave of the Cathedral at Wells: their diameter is 5.25 feet; their height 16 feet; and the intercolumniations 11.75 feet. The bases of the shafts resemble those called Attic, and stand upon triple plinths of circular forms, and the capitals are sculptured with elegant foliage. Similar columns appear in Henry VIIth's Chapel, at Westminster, and St. George's Chapel, at Windsor.

The forms of the arches in Gothic Cathedrals cannot be considered as affording sure indications of the Age of their construction. Semicircular arches were generally executed in the Saxon and Norman times, and when they occur, we seldom hesitate to consider them as belonging to one or other of those periods; nevertheless, several examples exist in which from an affectation of the ancient style, or from some other cause, such arches have been executed in later times. Again, the obtusely-pointed, or hyperbolic arch is not known to have been constructed till the time of Henry VII., but in the intermediate Age all the other varieties of the pointed arch seem to have been indifferently used. The high lancet-headed arch is considered as that which immediately succeeded the Norman kind; yet, in buildings of the same antiquity, we also find pointed arches differing but little from semicircles.

Writers on Gothic Architecture are accustomed to divide the pointed arch into several different kinds. Those the sides of which are described with radii greater than the breadth of the aperture, have the name of *lancet-head arches*, and the radii of these are sometimes equal to two or three times that breadth; and those, the radii of which are equal to the breadth, are called *equilateral*. But all those, the radii of which are less than the breadth, are distinguished by the names of *arches of the third point*, *fourth* point, &c.; in the first, the radii are equal to two-thirds; in the second, to three-fourths, of the span or breadth of aperture and so on: it must not, however be understood that in arches really constructed it is possible always to express the proportion of the radii to the span by terms so simple as these, for the artists do not seem to have limited their practice by rules, in this member more than in others.

The arches at the Eastern end of Canterbury Cathedral are of the third point, and this form seems to have been designedly given them from taste, for they are in situations where the high, lancet figure would have been more simple; since, in order to gain the required height, the artists have been obliged to make the curvature of the sides begin at a considerable distance above the capitals of the columns, which gives them in some measure the appearance of the horse-shoe arch. The importance which the Architects of that day attached to the elegant curvature of the arches is evident from the circumstance that those of the acutely-pointed form have, sometimes, each side described from two centres, in order to produce a greater degree of curvature on the hances than would be obtained by one centre. The Tudor arch is invariably of low elevation, the two sides forming a very obtuse angle at the vertex, and each side of these is usually supposed to have been described from two centres. In Henry VIIth's Chapel, at Westminster, the radii of the lower and upper part of the intrados are respectively equal to 0.217 and 0.845 of the span; while in St. George's Chapel, at Windsor, the radii are 0.2 and 1.25 of the span, respectively, and the proportions differ, perhaps, in every example.

Before the doorway of an ancient nunnery, at Rhodes, is an elliptical arch, above which is a projecting mass, like an oriel, consisting of three sides, with cylinders at the angles; the line of the arch is a curve of double curvature, as it projects forward so as to be every where vertically under the faces of the oriel, if it may be so called. In this last are windows, some of which have flat, elliptical, and others pointed heads.

The general profile of a pointed arch is splayed on each side of the intrados moulding, and, in this respect, it corresponds with the plan of the clustered column. No rule can be assigned for the breadth of the archivolt, if it may be so called, but cases occur in which, if we do not include the weather-moulding above the extrados, it is equal to half the breadth of the clustered column from which it springs, for the mouldings about two contiguous arches sometimes meet over the middle of the column; frequently, however, the breadth is less, and in some cases it is greater; in York Cathedral, the extrados-mouldings of two adjacent arches are made to intersect each other and come down upon the capital of the column in front of the interior mouldings. An elevation of one of the arches and pillars in the nave of Litchfield Cathedral is given at pl. xix. fig. 4; and of the arched gateway at King's College Chapel, Cambridge, at fig. 7, in the same plate.

The ornaments on the sides of arches are a series of slender astragal or bead-mouldings, the profiles of which are sometimes semicircular, at other times cuspid, and some have the forms of cymatia, or curves of contrary flexure of various kinds. The semicircular mouldings have, occasionally, a fillet or rectangular moulding on each side, and sometimes they are separated by a rectangular groove, or a circular channel, from each other. The weather, or extrados-mouldings, are in the form of cymatia, with a rectangular fillet on the exterior, and the lower extremity of each branch rests upon a Norman head, sometimes of a grotesque character, or upon an animal. In Beverley Minster it rests on an angel playing on a violin, and the angel stands on a head projecting from the wall over the column between the two arches.

Ranges of arches standing on small columns attached to the exterior and interior faces of walls, which form so conspicuous a feature in the Lombard Architecture, were adopted in the Gothic Churches of the North of Europe, but the arches, instead of being semicircular, correspond in form with those of the Age in which they were executed. In the oldest examples they are simply cuspid in the lancet style, and these are often used with semicircular arches in the same building, as is the case in the tower and gable at the Western end of Lincoln Cathedral. In the interior of the Chapter-house, at Salisbury, is a range of such arches having the intrados cut in cinquefoil shapes by segments of circles which meet and form rentrant cusps, and the upper segment has a point or salient cusp at the vertex. The Abbot's Tower, at Evesham, and the faces of the buttresses in that Church, are covered from top to bottom with tiers of cusp-headed, narrow arches in trefoil and cinquefoil forms. This tower was erected but a short time before the Reformation.

Sir Christopher Wren, though averse from the Gothic Architecture in general, and even censuring its taste severely, allows considerable merit to the pointed arch, on account of its mechanical properties; he observes that it can be raised with little centreing, it requires but light arch stones, and little abutment to resist its lateral thrust on the points of support. But with respect to its strength, Dr. Young, in his investigations concerning the strength of arches generally, published in the *Transactions of the Irish Academy*, has proved that when the radius of curvature is equal to two-thirds of the span, the strength of the pointed is to that of the semicircular arch as 0.826 to 1; and when the radius is equal to three-fourths of the span, the strengths are in the ratio of 0.795 to 1. Dr. Young also shows that the equilateral-pointed arch is the weakest of the kind, and that the strength is increased as the radius is less or greater than the breadth of the aperture.

An opinion of the relative strengths of the different kinds of pointed arches, founded on experiment, might have had some influence in determining the species to be employed in particular circumstances; for wherever great weight was to be supported it was usual, at the time of the first introduction of the pointed arch, to construct one, the branches of which were described from two centres near each other; which, consequently, differed but little from a semicircle; at the same time the arches merely ornamental were of the lancet form, very acute at the vertex; a construction probably chosen from some perception of its beauty.

Arches rising from pillars have always been objected to, but those of the pointed form rising from clustered columns, as in the Gothic Churches, do not seem so improper as those in the Roman and Saxon edifices; because the circular mouldings forming the ribs of the pointed arch appear to be but continuations of those which constitute the pillar, and the latter has the appearance of a bundle of rods which diverge from the capital and meet those of the neighbouring pillar in the vertex of the arch; consequently, the archivolt seems to form part of the pillar, and rather to be an ornament than a support to the wall above.

It may also be observed in favour of the pointed arch that it is easily adapted to any situation; for while the least irregularity in a semicircular arcade would produce an unpleasant effect, the other, possessing less unity of form, conceals many defects, and a series of such arches admits of considerable variations from equality of span without exhibiting an appearance of deformity.

Vaults.

In the ancient crypts, the hemicylindrical vaults, by their intersections, formed diagonal ridges, which were left without ornament, but a plain rib, projecting from the face of the vault, and extending from pier to pier perpendicularly across it, relieved the uniformity of the work. In the Church of St. Cross, in Hampshire, the diagonal ridge is cut off so as to leave a flat face, and this is ornamented with the double zig-zag, but the faces of the perpendicular ribs or cross springers are left plain.

The simple, hemicylindrical groin-vaulting of the Roman and Norman times seems to have been exchanged for that formed by the high-ridged vaulting as soon as the pointed arch had superseded the semicircular one; and the nature of the vaulting depends so much upon that of the simple arch, that there can be no difficulty in admitting that the profile of the former would always be made to correspond with the latter. In Salisbury Cathedral, ribs are formed at the diagonals of the groins and there is one cross springer between every two of these, in a vertical plane perpendicular to the direction of the vault; all these are ornamented with mouldings, and the intersections at the crown are marked by knots of foliage. In Winchester Cathedral the diagonal ribs intersect each other where the vertices of the lateral vaults meet that of the nave, and proceed thence to the longitudinal ridge in the crown of the latter, at which they meet those ribs which are in a plane perpendicular to its length. The upper parts of the divisions between the diagonal and perpendicular ribs are again divided by short ribs, extending to the crown of the vault and connected with the principal ribs by branches. Similar arrangements of ribs are formed on the faces of the lateral vaults, and the intersections of the ribs and branches produce a complicated tracery, almost every angle of which is marked by a knot of foliage. Over the choir of York Cathedral the tracery is still more intricate; the lateral vaults have the same height as the general longitudinal vault of the roof, and the spandril between every two of the former is divided into fourteen triangular compartments, on each side of the building, by three ribs which spring from the column, like those at Winchester, and by others which intersect them in various directions; and every intersection is marked by a flower. The kinds of tracery above described are supposed by Sir Christopher Wren to have been invented by the Freemasons: the ribs were commonly made of free-stone, and the intervals filled with light materials, sometimes with chalk.

The specimens of vaulting executed in the Age of the Tudors, and exhibited in the Chapels at Westminster and Cambridge, have been already described; the fan-work ornament and the pendent spandrils, in which the Gothic Architecture displays its richest character, may be considered as belonging to the last stage of Architectural luxury; artists, perhaps, could go no further in the indulgence of a taste for ornament, and, from that time, they seem to have reverted to a more simple style.

172. The entrances to Gothic Churches, both of the Norman and succeeding styles, are very small if compared with those of the Greek and Roman Temples. In general, the former consists of an aperture terminated by a semicircular or pointed arch resting on piers and preceded by a porch of a trumpet form, being small at the door and increasing in width towards the exterior both at the sides and crown; and, in some cases, the pavement of the Church is lower than the general level of the surrounding ground, so that the entrance resembles that of a Tomb, an idea of which it might have been intended to convey by that descent. In some Cathedrals, as in that of Winchester and Litchfield, a single pillar of small height is placed in the centre of the doorway, and from its capital rise two branches, making with the curve on each side of the doorway two pointed arches, the heads of which are included within that of the porch; each side of the entrance is generally ornamented with a multitude of slender columns, from the capitals of which stems proceed to meet those from the opposite side, at the vertex. The shafts are sometimes plain, but they are often enriched with an endless variety of sculpture, representing foliage and other ornamental objects. In small Churches the sides of the doorway are merely occupied by mouldings, the profiles of which are concave and convex curves.

The upper part of doorways in the Tudor Age was often inscribed in a rectangular recess or panel; a mode which we have stated to have been practised in the Moorish edifices at a period, probably, not much anterior to that of its introduction to this Country.

In almost every case the sides of pointed arches rise perpendicularly to the horizon, but there are some buildings in which those over doorways or windows do not so; such arches, which are very deficient in elegance, are found in Romsey Church and Winchester Cathedral, and they seem like the segments of pointed arches, formed by cutting away some of the lower courses of masonry. The doorway of Magdalen College, Oxford, is crowned by a low pointed arch of the hyperbolic kind, and this is within a rectangular recess, above which is a series of battlements, having small canopied niches containing statues in the faces of the merlons. Above the hances of the arch are armorial bearings, and on each side, from the exterior of the recess, springs a slender rib of a hyperbolic form; the two ribs meet on the middle of the exterior face of the horizontal mouldings over the doorway, and, except at the foot and vertex, they stand quite detached from the rest of the work.

Among the Greeks and Romans, the doorways were made proportional to the size of the building, and extravagantly lofty, but the Gothic Architects, who seem to have felt the impropriety of this practice, generally made them of nearly the same height for all buildings, and that was just sufficient for the passage of persons through them; yet, wishing to give them a suitable proportion to the size of the building itself, they contrived an ingenious way to combine both propriety and proportion by splaying the opening in oblique directions from the inner to the outer face in the thickness of the wall; thus converting it into a porch the sides of which they ornamented with columns, mouldings, statues, or foliage, by which it acquired an air of grandeur and beauty.

Windows. In the Norman Churches the windows were generally small, and consisted of narrow, semicircular-headed apertures, splayed interiorly, and placed singly in the sides, but two or three together at each end of the building, with a small, circular aperture above them in the gable; and, probably, in the smaller Churches, they were without glass. To these succeeded the lancet-headed windows, which were sometimes plain, like those of the Norman kind before mentioned, but at other times they were decorated, inside and out, with marble columns, of which those in the inside, as in Chester Cathedral, were detached from the wall; the proportion between the height and breadth of such windows is very various, but the ratios of 3 to 1 and of 7 to 1 seem to have been the limits.

In buildings of the XIIIth century, the windows were broader in proportion to their height, and were divided into two apertures, days, or lights, by a column, or mullion. The window was splayed on all sides towards the interior, and each aperture was covered by a pointed arch, either plain, or having the intrados cut in trefoils or cinquefoils, and these were either simple or cuspid. Above the apertures, but within the exterior arch, was a quatrefoil inscribed in a circle, or the mullion diverged at top, and formed three compartments ornamented in a similar manner. The window at the Eastern end of Lincoln Cathedral is of this kind, but its tracery is more complex. See pl. xix. fig. 1.

The species of ornament, which consists of circles either plain, or having the interior circumference cut in segments, is exhibited also in the heads of the windows of Churches erected in France during the same period, and it constitutes the first step towards the formation of the more complicated tracery which succeeded when the broad windows were divided into three or more parts by mullions. For then, above the trefoil or cinquefoil heads, which, at the level of the foot of the arch, terminate the vertical divisions, the mullions branched off in curves to the right and left, and formed, by their meetings or intersections, a number of loops, which occupy all the upper part of the windows; the edges of the loops were cut to form salient and rentrant cusps, which give to the loops the appearance of leaves of plants. Where the number of vertical mullions was uneven, as in Worsted Church, and Cawston Church, Norfolk, the central mullion divided into two branches, which meeting the mouldings on the curved sides of the window formed with them two pointed arches, and divided the upper part of the window into three principal compartments, each of which was occupied by the cuspid loops formed by the smaller ramifications. The whole height of such windows exceeded their breadth in various proportions, of which the ratios of 1.5 to 1 and 2.3 to 1 seem to have been nearly the extremes. The style may be considered as belonging to the XIVth century, and the different specimens exhibit a great variety of design. See pl. xix. fig. 2, which exhibits the upper part of the great Western window in York Cathedral

It is uncertain whether the mullions in windows originated from the practice of placing in the middle of an aperture a column for the support of its crown, or from placing two tall and narrow windows near each other, for the purpose of obtaining more light in the interior of the building; in the latter case the part of the wall between the windows, being gradually lessened, might ultimately become merely a vertical bar. The nearest sides of two lancet arches being supported on such a bar, have the appearance of two branches proceeding from the trunk of a tree; and, from this circumstance, it is not improbable that the idea of giving to the tracery in the heads of windows the appearance of foliage might have been taken. Be this as it may, we find that in the Eastern window of the Church at Dorchester, is actually represented a tree, exhibiting the genealogy of the family of Jesse. The central mullion forms the trunk, and, in place of transoms, branches proceed from this to the right and left, and are ornamented with sculptured leaves. There is also a mullion of the same kind on each side of, and parallel to the principal one; each of the three divides into two parts near the top, and these, by intersecting each other, form lancet-headed apertures, the interior edges of which are cuspid. On the mullions are sculptured statues, and a statue of the root of the family lies at the foot of the central trunk. See Britton's *Architectural Antiquities*, vol. v.

But from the middle of the XIVth century the foliate tracery was superseded, and a rectilinear division of windows seems to have prevailed, of which the great pointed window at the Western end of Winchester Cathedral is a striking example. This extends from the top of the doorway to the crown of the vault over the nave, a space equal to three-fourths of the height of the crown of the vault from the pavement, and its breadth is equal to that of the nave. Two principal mullions divide it into three equal parts vertically from top to bottom; and, in the interior, these mullions being continued downward, form the sides of the doorway; each part is subdivided into three others by smaller vertical mullions extending to the curved sides of the head, and these also are continued down to the pavement, except where the doorway interferes. Four horizontal transoms divide all the space, from the bottom of the window to the springing of the arch, into four equal parts, so that the rectangular part of the window is divided into thirty-six compartments, each of which is terminated by a trefoil cuspid head. At the level of the springing of the arch, the two principal mullions divide; one part goes up vertically to the head of the window, the other goes off laterally in a curve to meet the sides of the arch, by which are formed two secondary pointed arches; and all the compartments in the upper part of the window have cuspid heads like those below. According to Mr. Britton, this window was executed in the time of Bishop Wykeham, about the end of the XIVth century.

The windows in the tower of the Church of St. Mary, at Taunton, (see pl. xix. fig. 3.) may be considered as examples of the style of executing them about the middle of the XVth century. Some of these windows have curved tops higher than those of the equilateral kind, but others are more flat, and seem to approach the hyperbolic form, which prevailed about half a century later. Like the window at Winchester, the part below the springing of the arched head is divided into rectangular compartments, each of which is terminated by a cinquefoil, cuspid head; within the upper part, short upright bars rise from the vertices of the cinquefoil heads, and every two are connected at top by others which meet at an angle; from the vertices of these proceed other upright bars which are connected in the same manner, and this arrangement is continued to the top of the window, so that all the space within the arch is occupied by hexagonal compartments, every one of which is subdivided into four similar hexagons.

The species of ornament which consists in an union of polygonal figures, or of circles, is called by Mr. Rickman *Geometrical tracery;* a term sufficiently proper to distinguish it from that kind which is formed by curves of a complex nature.

When the Tudor arch was introduced, the compartments formed by the mullions and transoms were larger than before, but the manner of ornamenting them was nearly the same as in the windows last described. Finally, the breadths of the windows became greater than their heights, and the tops were made horizontal; the breadth was then divided by one or more vertical mullions, and there was sometimes no transom. The rectangular apertures were either not ornamented, or their upper extremities were formed with semicircular or cuspid heads; the latter were sometimes of contrary flexure, and there was a loop cusp on each side, as in some of the windows of Hampton Court Palace.

The weather, or hood-moulding seems to have been an almost universal accompaniment to a Gothic arch, both on the exterior and in the interior of a building, and, except when it became rectilinear or a curve of contrary flexure, its form corresponded with that of the head of the aperture, so that, when the latter became horizontal, the weather-moulding was also rectilinear.

Over a recess in the peristyle of Dioclesian's Palace we find an example of the arch of contrary flexure, which, though it is, probably, more modern than the rest of the building, is likely to have been the first of its kind. The same species of arch, and the rectilinear pediments employed as ornaments above apertures or recesses, are very common in the Ecclesiastical buildings of the Continent; but whether their application in these examples was previous or subsequent to their introduction in this Country does not appear.

A circular aperture is, perhaps, one of the most ancient methods of obtaining light for the upper part of the interior of any building. The Greeks and Romans, who gave rather low roofs to their edifices, had little occasion to make any aperture in the tympanum of their pediments; and, therefore, we do not find it in any of their buildings, except in the interior of the Palace at Spalatro, where, on one side of the peristyle is a circular window of small dimensions; this is, probably, the first of the kind now remaining, and it may have been executed at some period subsequent to the erection of the building. The same kind of aperture was formed in the Christian Churches erected at Rome, and thence the practice may have extended to those of Germany and France. In England, we find it not only in buildings erected subsequently to the Conquest, but also in those of Saxon or Norman origin.

But the taste for improvement increasing, the simple circular aperture was soon, in this Country at least, changed for one formed by three or more segments of circles meeting in rentrant points, and constituting what are called trefoils, quatrefoils, &c.; these were employed not only in the pediments or gables of buildings, but in the wall between the arched heads of doors and long windows, and even in the compartments of windows themselves between the branches of the mullions, as in Lincoln Cathedral.

The resemblance of the circular aperture to the wheel of a carriage probably led to the practice of making it large, and supporting its circumference by bars radiating from a centre; this, which is called the *Catherine-wheel*, is thought to have been first constructed in France, from whence it seems to have been introduced into this Country soon after the Norman style was superseded, and an elegant specimen of it, in its simple state, yet remains in the Southern transept of Beverley Minster. But the increased size of the windows in the next Age of Architecture rendered it necessary to introduce a greater number of bars; and, as these might have been either too far asunder, or too much crowded if they all extended from the centre to the circumference, it was found convenient to divide the window into two by another circle concentric with the first; the radii of the interior circle were continued to the circumference of the exterior one, and within the annulus only, additional bars were inserted in the direction of radii. Such a window as this occurs in the Southern front of York Cathedral; its radii resemble short columns, the tops of which are joined by small arches, and the centre is occupied by an elegant rose.

But the tracery which had been introduced within the arched tops of great windows, was extended to those which were circular, and we find the compartments of the latter afterward, that is, in the XIVth century, made to resemble those of the former; and, according to the form assumed by the ramification of the bars, the aperture had the name of a *rose*, or a *marigold window*. In the Northern and Southern extremities of the transept of Westminster Abbey are immense circular windows, 32 feet diameter, with radiating mullions, each of which, near the exterior, divides into two parts, and the branches form cusps, the vertices of which are on the circumference; between the principal mullions are secondary ones, also in the direction of radii, and forming cusps at their extremities, and within the compartments are quatrefoil perforations. The great circle is inscribed in a square, and within each of the four angles of the latter is a large quatrefoil inscribed in a circle. These windows are of later date than the part of the building in which they are placed, and Mr. Pugin supposes them to have been added in the time of Richard II. In the Western façades of the Cathedrals of Notre Dame at Paris and Rouen are great circular windows, in the centres of which are rich flowers, and between these and the circumferences the aperture is occupied by narrow loops in the directions of the radii. At each extremity of the transept of Lincoln Cathedral is a circular window in which are formed four compartments by two arches of circles, the centres of which are in the circumference of the exterior circle, and the circumferences touch at its centre; in the middle of each of these is a vertical stem from which branches proceed to the right and left, and form loops, the interior edges of which are cut to represent circular and cuspid foliage. The divisions of circular windows sometimes consist of an annulus of quatrefoil perforations inscribed in circles which are disposed about one in the centre; and this itself is composed of circular perforations similarly situated.

Towers and spires.

Some of the oldest towers of Churches in this Country are of a cylindrical form, pierced with small apertures or loop-holes and crowned by battlements. The towers of the Norman Churches were generally square, ending in battlements, and perforated by several tiers of circular-headed windows, or ornamented with arcades of the same kind, disposed also in tiers on the faces of the walls. The tower of Ely Cathedral, which is supposed to have been built in the latter end of the XIIth century, is a decagonal prism divided by eight tiers of windows and arcades, of which the three lower have semicircular heads; the others are formed with pointed or trefoil arches, and the whole is crowned by battlements.

After the pointed arch was introduced, spires were occasionally employed; but generally the roofs of towers were flat, and at the angles were plain or ornamented pinnacles, with buttresses for their support.

As opinions have been various concerning the origin of the pointed arch, so have they been also concerning the origin of the spires which crown the towers of Churches. Dr. Milner supposes that buttresses which were found necessary for the support of walls could not be properly finished but by forming pinnacles at the tops; and these being enlarged became spires: others have deduced them from the Egyptian Obelisks, which they consider as merely ornamental objects: again, others derive them from the Pyramids, which, by all people, have been used to mark the burial places of their distinguishd characters; and they suppose them to have been applied to Churches when the latter were used for the like purpose. In England, the spire is placed above the tower, as if it had been a subsequent addition, and not part of the original idea; and, in fact, the earlier Churches, or those erected during the prevalence of the Norman style, are merely crowned by battlements or plain parapets, and the pinnacles, which are sometimes formed on those buildings, are invariably of a later date than the building itself. One of the earliest spires known was that of the old Cathedral of St. Paul, in London, which was built about the year 1222, of timber, and covered with lead: many such were afterwards constructed, but being often destroyed, they were, finally, built of stone. Of this material, the first executed is that of Salisbury Cathedral, which was erected about 1429, and since repaired by Sir Christopher Wren. From that time hardly any Ecclesiastical edifice was raised without one, and they are in general highly ornamented with sculpture.

While the Pointed Style was in high vogue, the towers and spires were extremely lofty, particularly that which was placed over the intersection of the nave and transept; the top of the spire being, in some cases, as far from the pavement as seven times the height of the roof of the Church. The towers at the Western end were commonly ornamented with arches and windows to correspond with those in the wall of the nave between them, but the central tower had commonly two tiers of windows on each face, with the ornaments about them belonging to the time of their erection; generally a pediment in the form of a curve of contrary flexure, with crockets and finials as usual. The merlons of the battlements were either solid or open, and a pinnacle was placed at each angle. From the centre of the tower rose the spire, generally in the form of an octagonal pyramid, the edges of which were ornamented with bosses or foliage; but the most remarkable circumstance in the spire is its slender profile; that of Salisbury Cathedral is only two feet thick at the base and nine inches at the summit. It is worthy of remark that frequently the choir being less broad than the nave, the four columns supporting the central tower are, in such cases, disposed at the four angles of a trapezoid instead of a square; and the Northern and Southern faces of the tower are consequently not parallel to each other, nor to the side walls of the building.

A curious specimen of a spire is that of the Church at Newcastle on Tyne, which is thus constructed; from each of the four angles of the square tower springs a strong rib of masonry in the form of a quadrant of a circle, and without a spandril; these meet over the centre of the tower, and upon the intersection is raised a square open lantern, crowned by battlements, and having a small pinnacle at each angle; and from the centre of this rises a lofty pyramidal spire ornamented with crockets. At each angle of the great tower is a slender, octagonal turret, with battlements at the height of the vertex of the arch formed by the four ribs, and above each of these is an ornamented pinnacle; and a smaller turret and pinnacle is placed between every two of these on the middle of each face of the tower. The tower is said to have been added to the Church in the reign of Henry VI. This example of a spire supported on the intersection of four open ribs suggested, no doubt, to Sir Christopher Wren the design which he put in practice at the Church of St. Dunstan in the East, in London.

Buttresses. The buttresses attached to the Norman Churches have been already described; we purpose, therefore, in this place to speak of those only which were constructed after the Pointed Architecture became general; from which time they were embellished with decorations corresponding to those on the other parts of the building.

In the first period of that style of building, the buttresses were made of equal breadth and depth, nearly from top to bottom, and they terminated above in high pediments or gables, within which, on the face was, sometimes, a trefoil, cuspid, ornamental arch supported by two small pillars: such are the buttresses at Beverley Minster, in Yorkshire; and in these a rectangular notch is cut along each of the exterior angles of the buttress in a vertical direction, within which is a slender reed column with a small base and capital. At the Eastern end of Lincoln Cathedral are buttresses similar to these, but more ornamented; the edges of the gable tops are decorated with crockets and finials; on the face is a panel formed between the reed columns at the angles, and terminated by a small, pointed arch near the top; and at two places in the height are formed trefoil-arch heads with a small, rectilinear pediment above. Each side of the buttress is ornamented in a manner exactly similar to the face.

In later buildings, they were divided horizontally into several parts, each projecting more than that above it, and the heads of the inferior parts were covered by small inclined planes, or water-tables. In some cases the upper division of the buttress is attached to the face of the wall by short ribs only, and the whole is then crowned by an ornamented pinnacle quite detached from the building. The angular buttresses are not always placed immediately at the quoins of the building, but a little way from them, so that small portions of the walls appear in the rentrant angle formed between their nearest sides. The vertical buttresses of Henry the VIIth's Chapel at Westminster have been described in speaking of the style of Architecture in the XVth century.

What are called flying, or arched buttresses, are generally only ribs of masonry extending from the solid buttresses attached to the walls of the aisles to the upper part of the side walls of the central division of the nave or transept; they are sometimes formed of simple voussoirs without spandrils, and the extrados is usually in the shape of a roof, being covered by two inclined planes which meet in a ridge. But the arched buttresses of Henry the VIIth's Chapel consist, each, of two double ribs one below the other; the inferior rib of each pair is in the form of an arch of a circle, and the superior rib of the lower pair is rectilinear, while that of the upper pair is a curve concave upward; the superior surface of this rib is ornamented with creeping animals, seeming to descend along the rib, and between the two pairs, are perforations in the form of quatrefoils, or loops, inscribed in circles, by which the massive appearance of the buttresses is removed without much diminishing their strength.

Pinnacles. The earliest pinnacles were, probably, only conical terminations at the tops of round towers, and when afterwards polygonal towers were erected, the pinnacles above them necessarily became pyramids. Along the ridges of these, were reed mouldings, and they were frequently adorned with small crockets, as is the case with some of those on Salisbury Cathedral, and occasionally the upper extremity terminated in a finial. The pinnacle was generally mounted on a small prism, in each face of which was an aperture or a recess terminated by a small arch, either semicircular or pointed, and then a rectilinear pediment crowning each arch; smaller pinnacles were sometimes disposed about the base of the principal one, and these were enriched in a similar way.

From the end of the XIIth century pinnacles were almost always placed on the tops of buttresses, and those of Lincoln Cathedral, (pl. xix. fig. 9.) may serve as specimens of the manner of ornamenting them. Each face of the buttress is crowned by a pediment or gable, the height of which is equal to about twice its breadth; the figure of a beast projects forward horizontally from each of the lower extremities of the gable and the sides, which are ornamented with crockets, terminated in a finial. Between the sides of the gables, rises an octagonal turret with a reed column at each angle and a lofty gable over each face; the whole height of the turret, from the bases of the gables below to the summits of those above, is equal to about three times its diameter, and the latter gables are ornamented with finials only. Lastly, between the sides of these, rises an octagonal pyramid to such a height that the distance of its apex from the bases of the lower gables is five times the diameter of the turret; the ridges are ornamented with small scrolls, and the pyramid is crowned by an elegant finial.

In edifices, the towers of which are very much enriched, the figure of a bird, animal, or a man frequently projects horizontally to a considerable distance from each angle of the tower, and supports a square pillar or small clustered column terminating in an ornamented pinnacle; the whole pillar is detached from the turret or great pinnacle in front of which it is placed, except near the upper extremity, where it is connected with it by a bar or piece of open-work. This kind of ornament is exemplified in the tower of St. Mary Magadalen's Church at Taunton.

The form of the pinnacles employed in the Tudor Age, has been described in speaking of the general style of Architecture practised in the XVth century. Pl. xix. fig. 6, is an elevation of a pinnacle on one of the buttresses of Henry the VIIth's Chapel at Westminster.

Niches seem to have been a late addition to Gothic Churches, and were made, on the exterior, to contain statues, or in the interior to contain tombs or piscinas. The simplest and earliest constructed were rectangular on the plan, but with the progress of luxury, they became hexagonal and even octagonal, and were adorned with every variety of sculpture. On the exterior of the building they were placed indifferently in the towers, buttresses, and walls; and, often, they were disposed in horizontal ranges along the Western front, above and on each side of the doorway.

In front of the recess containing a piscina, in Salisbury Cathedral, are three columns, with circular bases and capitals, which support two pointed arches, the intradosses of which are cut to form trefoil heads, and the exterior of the recess is surrounded by a circular moulding disposed on the four sides of a rectangle described on the face of the wall; this is one of the most simple forms. In later times, the upper part of the face of the recess was a pointed arch, the sides of which were cut to form rentrant cusps, the latter ornamented with foliage, the curves with mouldings, and the lower extremities resting on single or clustered columns of small height. Frequently, this kind of façade was crowned by a pediment with sides either rectilinear or in the form of curves of contrary flexure, and decorated with the usual ornaments; and on each side of the recess was a buttress or pillar terminating in an ornamented pinnacle.

In the more enriched works, when the recess is of a polygonal form, the interior sides are ornamented with rows of panelling having trefoil or other curvilinear heads; at the upper part of the niche is a canopy projecting before it in the form of three sides of a prism, the lower extremity of each face is cut in a trefoil or quatrefoil arch, above which is a pediment ornamented with crockets and a finial; and between these arches, that is at the angles of the prism, is a small pinnacle ornamented as before, and rising as high as the level of the ornaments above the arches, but terminating at the lower extremities of the same arches, so that they seem suspended in the air, and resemble the tops of buttresses or piers of which the lower parts have been removed. Sometimes the whole of the upper extremity of the canopy is ornamented with fleurons, and on the sides which are attached to the walls are columns, single or clustered, or slender piers ornamented in the same style as the canopy and interior of the recess.

Shrines or sacella were commonly tombs placed in recesses of the walls in the interior of Cathedrals, and originally they consisted of plain sarcophagi or coffins, with little other sculpture than the recumbent figure placed upon them; afterwards, the recess was formed with an arched front ornamented with foliage, and at a still later period it was enriched with elegant canopies executed with open sculpture or filigree work. Finally, the shrine became a splendid Chapel like that of Henry the VIIth at Westminster.

Bishop Bridport's monument in Salisbury Cathedral, is a rectangular space in the body of the Church. In front are two pointed arches of the equilateral kind with concave and convex mouldings; each of the two outer branches rests upon two small pillars a little detached from each other, with circular bases and capitals which unite together, and the two adjacent branches rest upon three similar pillars. Each aperture is divided into two, by a single pillar of the same kind as the others; these apertures are crowned by smaller, pointed arches nearly equilateral, and having the intradosses cut in trefoils with cuspid heads, and the whole of the spandril between these and the exterior arches is perforated in the form of a quatrefoil enclosed in a circle. Over the extrados of each principal arch is a rectilinear pediment with crockets and finial; and its lower extremities rest on fanciful figures projecting from the wall. At each extremity of the front is a column, with a circular base and capital, as high as the tops of the principal arches, and above the capital is a base surrounded and surmounted by foliage; a small column, similarly crowned, stands over the centre columns, on the face of the tomb, above the meeting of the adjacent faces of the pediments. On the face of the wall between, and on each side of the pediments, are figures of Angels and human beings in the act of adoration.

In Westminster Abbey, the Tomb of the Countess Aveline, who died in 1275, is one of the earliest specimens of sepulchral monuments in the Gothic style. It consists of a sarcophagus surmounted by a pyramidal canopy; the front is divided into six parts by graduated buttresses enriched with crockets and finials; in each compartment is a small figure standing within a trefoil-headed recess, under an angular pediment which is ornamented like the buttresses, and within the angle over each recess is a circle enclosing a quatrefoil. The surmounting canopy is supported on each side by a pier-buttress, sculptured with panelled arches and large crockets of oak leaves. In the recessed part or tympanum of the pediment is a compartment formed by curvilinear mouldings, within which are traces of an historical painting; the under part of the pediment is formed into a gracefully-pointed arch springing from a small column at each angle, and having its architrave studded with roses, and within this is a kind of trefoil arch rising from the outer capitals of the clustered shafts which sustain the archivolt. The front spandrils are sculptured in mezzo relievo with a vine branch and acanthus. (Britton's *Architectural Antiquities*, vol. v.)

Observations on Gothic Architecture.

In the Grecian Architecture it seems to have been an object of importance to preserve the horizontal lines of the buildings unbroken, in order to convey with facility to the mind a perception of their lengths, while a truly vertical line scarcely appears. In the Gothic Architecture, on the contrary, we find an effort constantly made to exhibit a system of vertical lines; this is evident, not only on the exterior of the building, where they are strongly marked by numerous lofty buttresses extending from the ground to the summits of the walls and towers, but also in the interior, where slender shafts rise from the clustered columns in the lower arcades, pass between the arches of the triforia and proceed to the springing of the vault, thus indicating at a glance the whole height of the edifice. The system of horizontal lines is, however, not neglected in the Gothic buildings, and the ranges of arcades and windows serve, perhaps, sufficiently to indicate the extent of the edifice in that direction; these features being wanting to the Grecian Temples, the system of horizontal mouldings along the building was, in them, essentially necessary.

The fillets placed at intervals across the shafts of the Gothic columns are not so great either in height or projection as to interfere much with the continuity of their vertical lines, and they just serve to obviate the effect arising from the disproportion of the height of the shaft to its diameter, by giving to the whole the appearance of several columns placed one on another.

In the Grecian Temple, all the powers of the artist were expended on the exterior, and a spectator on entering such a building would certainly be disappointed to find that so much magnificence led to a cell enclosed by four naked walls. Within the Gothic Cathedral, on the contrary, every variety of feature and ornament seems to have been exhausted; the ranges of columns, arches, and vaults produce, when seen in perspective, an appearance which the mind dwells on with surprise and pleasure; and which, jointly with the richness of the decoration, seems to render the building worthy of the Deity to whose service it is consecrated.

In the Middle Ages the Ecclesiastics engrossed nearly all the wealth, and it may be added, almost all the talent of Europe. With such means, and a disposition to increase their power over the minds of men by every circumstance which could inspire reverence, and the ambition of excelling each other in the splendour of their establishments, it is easy to conceive that the energies of their minds would be directed to the building and adorning of their Cathedral or Conventual Churches with the highest possible degree of magnificence. We are not, however, to consider any of the great Cathedrals of Europe as the work of one person, or even of one Age; the practice seems to have been for some Prelate to give the design, and to execute only as much as was in his power; this part was consecrated and employed for Divine Service, and it was left for succeeding Prelates to carry on the work till it should be completed. This accounts for the variety of style observable in different parts of the same edifice; a variety independent of that produced by the repair of such parts as became dilapidated by time or accident; and also for the circumstance that many of our old Churches are, even now, in an unfinished state; the Reformation and the Dissolution of Monasteries having broken that chain of operations, which had been going on for Ages, before the design was completed.

CHAPTER IX.

Ancient Indian Architecture.

Nature of the Architectural works in India.

The Architecture of India is worthy of the serious attention of Europeans, both from its style and execution, and we devote the present Chapter to a description of the principal monuments of the Art in that Country, which, according to the accounts of travellers, abounds with stupendous excavations and magnificent buildings for Religious purposes, displaying a profuse expenditure of wealth and labour.

From the excavated rocks which have been discovered in that Country, resembling in form, though not in embellishment, those of Egypt and Persia, and, like them, seeming to be destined for Tombs or Temples, there has arisen an opinion that they have claims to an antiquity at least equal to that of the Egyptian works. These claims, however, are unsupported by any Historical evidence like that which we possess in favour of the Architecture of Egypt. We are utterly ignorant of the time of the formation of any one of the excavations, and there are many circumstances which justify an opinion that none of them are much more ancient than the period of the conquest of the Country by the Mohammedans, which took place during and after the XIth century. The Temples raised from the ground are, with great probability, referred to a still later period; and it is from these circumstances that we think it proper to introduce the account of Indian Architecture in this part of the Work.

Of the excavations, the most magnificent are those at Adjuntah or Nizamabad, and Elora in the Khandesh; and those in the Islands of Elephanta and Salsette near Bombay.

Caves at Adjuntah.

The caves at Adjuntah, which were visited by Lieutenant Alexander in 1824, are described by that gentleman nearly in the following manner. They are disposed in series rising gradually above each other, at the termination of a glen remarkable for picturesque beauty, and are excavated in horizontal strata of greywacke with imbedded portions of quartz; the lower cave is about 40 or 50 feet above the rivulet Nullah, on the Northern face of a ridge of hills; those of the centre are about 150 feet from the stream; and the most remote is in the vicinity of a bluff rock of 200 feet elevation. These stupendous remains of antiquity and Art are mostly formed with low roofs, supported by massive pillars having cushioned or globular capitals which have received but little ornament from the chisel. In many of the caves are paintings in fresco representing the dresses, habits of life, pursuits, and general features of the Jains, the crisp-haired Aborigines of India, who, according to tradition, were driven from thence after the introduction of Brahmanism.

The principal cave, forming the grand Temple, is at about 150 feet from the bed of the Nullah. On the face of the hill, jungle and brushwood surround the entrance, which is very striking, having in the centre an arch of the horse-shoe form, with a colossal Jainter 10 or 12 feet high on either side. In the interior is a well-lighted hall, about 25 feet high, the roof of which is of a form nearly semicircular without ribs of any sort, and supported by hexagonal pillars which, as well as the entablature, are unornamented. Opposite to the entrance, and about 30 feet from it, is what has been supposed to be a circular Temple, but which Mr. Alexander considers as a rostrum merely, from which the Priests of Boodh recited prayers in public; it is a hemisphere of solid stone, resting on a pedestal something larger than itself, and surmounted by a square block, resembling the capital of a pillar. Some of these excavations, he supposes, were converted by the Portuguese into places of worship; and adjoining the large cave are several cells furnished with stone bed-places, and seeming to have been the abodes of devotees.

The other caves, which are all flat-roofed, are in good preservation, and one of them consists of two tiers of excavated rock, in one of which are fluted pilasters.

chitecture.

The paintings in many of the caves represent battles and hunting scenes, in which the elephants and horses are well executed; and there is what seems a representation of a zodiac, not, however, resembling that at Tentyris in Egypt.

Elora,

The caves of ELORA have been fully described in our *Miscellaneous Division*. A front view of *Indra-sab'hà* is given in pl. xxi.

According to information given to Sir C. W. Malet, the works at Elora were executed about A. D. 900, by Elloo, the Rajah of Ellichpour, who at that time is said to have built the town; but it is evident that no dependence can be placed upon an account which is unsupported by any inscription or other Historical document. The late Dr. Heber, Bishop of Calcutta, remarks that the excavations are not mentioned, even incidentally, in any Sanscrit manuscript, and that the Images they contain are the same that are now worshipped in every part of India; and his Lordship concludes that they have been formed in a time of Peace, under a Hindoo Prince; therefore, either before the first Afghan Conquest, which took place in the XIIth century, or subsequently, during the recovered independence of that part of Khandesh and the Dekan.

Carli,

Excavations similar to those at Elora exist at Carli on the neighbouring coast; the roof of one of the latter, like that of Biskurma, is in the form of a Gothic vault; but the ribs, instead of being of stone, are formed of teak-wood, and are attached to the rock by wooden pins.

Ele-nta,

At Elephanta is a grand Temple excavated in the rock, 120 feet square on the plan and 18 feet high, and having a flat roof supported by four rows of columns. The columns are about 9 feet high, formed like balusters, and covered with vertical channels; they are supported on pedestals, the height of which is about two-thirds of that of the columns. Above each capital is a block, on which rests a horizontal architrave of stone extending along the tops of the columns in each row. Along the sides of the cavern are forty or fifty colossal statues, from 12 to 15 feet high, attached to the rock; some with pyramidal helmets, and others with crowns; some with four hands and others with six. At the Western end of the cavern is a dark recess 20 feet square, which is entered by four doors, and there are two gigantic figures at each door; this recess is without ornament, but there is an altar in the centre.

naran.

Excavations similar to those at Elora and Elephanta have also been made at Canarah, in the Island of Salsette, near Bombay. The front of these is formed by cutting away one side of the rock as before, and there are four stories of galleries, containing in all three hundred apartments. Before the entrance to the principal Temple, is a portico with columns; the length of the interior of the Temple is 84 feet, and its breadth 46 feet; its roof is vaulted, and the height is 40 feet from the ground to the top of the arch. The vault is supported by thirty-five octagonal pillars, each five feet in diameter, and their bases and capitals are formed of elephants, horses, and tigers. Round the walls are two rows of cavities for lamps; at the further end is an altar 27 feet high and 20 feet in diameter, and over it is a dome-vault cut out of the rock. The excavations are filled with Idols, and the walls are covered with sculpture representing men, women, elephants, horses, and lions.

Having described the principal Temples formed in India by excavating rocks, we are next to mention some of those which have been constructed of masonry; and in these we shall find proofs that the Art of Building, as well as of Sculpture, has long been cultivated with success in that part of Asia.

Part III.

Temple at Chillambaram,

At Chillambaram, on the coast of the Carnatic, is a cluster of pagodas within a rectangular space, 1332 feet long and 936 feet wide, enclosed by a wall 30 feet high and 7 feet thick; on each of the four sides of the wall is an entrance which is covered by a richly adorned pyramid. This general enclosure includes four particular ones, of which that in the centre contains a piscina, or basin for purification, surrounded by a colonnade and by steps to descend to the water; the second, which is on the Southern side, forms a cloister, in the midst of which are three contiguous Temples, called *Chabei*, which are lighted only by their doors, or by lamps: the third, which is on the West, forms also a cloister, and in the midst is an open portico supported by one hundred columns, bearing a roof formed of great stones, like those in the roofs of Egyptian buildings: the fourth, which joins the last, is a square court containing a Temple, and a piscina called the Stream of Eternal Joy. In front of this Temple is a portico of thirty-six columns disposed in four parallel rows: the breadth of the central interval is double that of the others, and in the midst of it is a platform, on which is placed a statue of the Bull Nundee. The Temple itself is filled with sculpture, but it receives no light except from lamps, which are carefully kept burning.

On the Eastern side of the central enclosure is a magnificent Temple raised on an elevated platform 224 feet long and 64 feet wide, and in front is a portico consisting of a thousand columns of blue granite; at the extremity of this portico is a square vestibule with four portals, the middle one of which leads to the Sanctuary, called *Nerta Chabei*, or the Temple of Joy and Eternity, at the extremity of which is the altar. The Temple is covered with sculpture, representing all the Divinities of India. At each side of the door of the *Nerta Chabei* is a highly-ornamented pilaster, (see pl. xxi.) but the greatest curiosity in the Temple is an immense chain of granite cut from the rock; it is attached to the pilasters, and is supported at four other points in the face of the rock so as to hang between them in festoons; each link is about three feet long, and the length of the whole chain is 146 feet. Similar stone chains are frequent in other parts of India.

The pyramids, which are placed over the entrances of the exterior enclosure, are formed on rectangular bases, and consist of several floors; a passage is made through them on the level of the ground, and on one side of this are the steps which lead to the floors above. One of these pyramids, represented in pl. xxi., is 160 feet high,* and composed of a stone basement having two open galleries, one above another, with pilasters in front, standing upon and supporting sculptured mouldings. Above these are seven floors, each of which is ornamented with bas-reliefs made of baked earth on a ground of white cement, and with little niches in the form of shells elegantly formed to receive lamps. Coussin, *Du Génie de l'Architecture.*

at Juggernaut,

At Juggernaut, on the coast of Orissa, about 300 miles from Calcutta, are three great Temples or Pagodas, each surrounded by a wall composed of great stones deposited without cement. At the entrance of the prin-

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* In our *Miscellaneous Division, ad v.* CHILLAMBARAM, we have given Lord Valentia's admeasurement, 122 feet, which is, probably, the more correct of the two.

cipal Temple is a pyramid 344 feet high, covered with sculpture. The Temple itself is built of immense blocks of granite, and the foundations are laid in the natural rock.

at Seringham.

One of the largest of these Temples at present known is situated at Seringham, a small Island near Trichinopoly, on the coast of Coromandel; it is contained within seven square enclosures, 350 feet distant from each other; the outer walls on each side of the square being one mile long, 25 feet high, and 4 feet thick. On each front there is a gate, and that on the Southern side is adorned with pillars, several of which consist of single stones 33 feet long and 5 feet in diameter.

Ruins at Bamiyan.

In a branch of the Caucasian mountains, between Bahlac and Cabul, are the remains of the ancient city of Bamiyan, consisting chiefly of apartments and recesses cut out of the rock, and adorned with niches and carved work; some of them, on account of their great dimensions, are supposed to have been Temples. On the summit of a conical hill are the remains of a Palace of the ancient Kings of this part of the Country, and round it are the ruins of several buildings executed in masonry. This city was destroyed by Genghiz Khan; therefore, the excavations must have been made before his time, and, probably, while the city was in the hands of the Tartarian Princes of Persia. *Asiatic Researches*, vol. vi.

Comparison of the Indian and Egyptian Architecture.

On reviewing the examples which have been described, we shall find that the resemblance of the ancient Indian Architecture to that of Egypt, with which it has been frequently compared, consists only in a few general circumstances. In both Countries, Temples have been excavated in mountains of stone, and the designs do not seem to have been subject to any system of proportions: the Indian columns are rectangular, polygonal, or circular, some are large at bottom and diminish upwards, while others are slender at bottom and thick above, in which respects they have certainly some similarity to the columns of Egypt. But if we descend to the particular forms, we shall find such differences in the works of the two people as to render the fact of the derivation of one style from the other extremely doubtful. In Egypt, the greatest solidity and simplicity prevailed; while, in India, as much lightness was given to the supports as is consistent with the mass they have to bear; and the exteriors of the edifices are adorned with elaborate sculptures in relief. The statues of Egypt and India are equally colossal, but the differences between them in respect of figure, position, and costume, will not permit us to consider them as emanating from a common source; and though the frequent introduction of the lotus-leaf into Indian Sculpture may appear to afford an argument in favour of that opinion, because that plant is one of the ornaments most generally exhibited in Egyptian works; yet much stress ought not, perhaps, to be laid on this circumstance, since the lotus abounds equally in Egypt and India, and might have been chosen by the artists of both nations as an appropriate subject for the chisel.

It has been observed by a late author that we find examples of the use of arches in India, and even constructions indicating that the feature originated in that Country; by arches, here, no doubt, are meant those horizontal courses of masonry overhanging each other and meeting at the top over the middle of the interval of the piers; but while we are ignorant of the date of the erection of any such arch in India, it will be unnecessary to suppose that the Egyptians or Greeks, who employed similar constructions, were indebted to the Indians for the first idea of them, since their simplicity is such that they could hardly fail to present themselves to the mind of a builder in any nation, even in the infancy of the Art.

In his observations on the general opinion of the great antiquity of the Indian Architecture, the Bishop of Calcutta remarks that there is a complex impression made on us by the sight of edifices so distant from our own Country, and so unlike what we have seen there, which makes us think them more ancient than they really are. The firmest masonry of India is sorely tried by the alternate influence of a pulverizing sun, and a continued three months' rain. The wild fig-tree, which it is a sin for a Hindoo to root out, sows its seeds and fixes its roots in the joints of arches; in a few years it increases the antique appearance, and brings on certain destruction. At Benares, the principal Temple appears so venerable that one might suppose it to have stood unaltered since the time of the Treta Yug; yet it is certain that it was built since the reign of Aurung Zebe, who was contemporary with Charles II. in England.

PART IV.

MODERN ARCHITECTURE.

CHAPTER I.

Revival of Roman Architecture in Italy.

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It has been the fate of every invention of the human mind which depends on Taste, to be cherished at first as a novelty, to be pursued for a time ardently to the exclusion of all other modes, to be cultivated till it has acquired all the embellishment of which it seems capable, and then, to be abandoned for some new form. This, in its turn, passes through the different stages of refinement, and, finally, gives place either to a third mode, or to some modification of those which preceded it. Such has been the case with the Greek Architecture, which having been overloaded with ornament by the Romans, gave way to the more simple style employed by the Saxons or Normans: from this arose the Florid Gothic, which, when it admitted no further enrichment, ceased to be the prevailing Taste of the Age, and gave way once more to the chaster styles of Greece and Rome.

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The capture of Constantinople by Mohammed II., induced the artists and men of learning who had hitherto been patronized in the Court of the successors of Constantine, to seek employment among the Nations in the West of Europe; and hence the Language and Literature of ancient Greece were introduced and became objects of study in that part of the World. The comparative freedom then enjoyed in the cities of Italy, which by commerce had acquired wealth and importance, elevating a great portion of mankind above the state of vassalage and ignorance, in which they had hitherto been held, gave them a relish for Science, Literature, and Art. A natural desire to possess private dwellings constructed with elegance, might operate powerfully to introduce an inquiry into the principles of Architecture; and as, during the prevalence of the Gothic systems of building, edifices for Civil and domestic purposes had been much neglected, all the energies of the artists being exhausted upon Ecclesiastical and Military structures, men might begin to look to the remaining buildings of ancient Rome, and to the writings of Vitruvius, for rules to guide them in their constructions. This would naturally give rise to an imitation of the Roman style in their Civil and Ecclesiastical edifices. Greece being at that time in the possession of the Turks, the Italian Artists may have had few opportunities of contemplating the splendid examples of Art then existing in good preservation in that Country; and, even if these had been more accessible, their deficiency in Taste would not have permitted them to execute any thing comparable to the productions of that School of Architecture.

Gothic Architecture fell into disrepute.

That which ceases to be the favourite mode soon becomes despised, and, accordingly, in the Works of most of the writers who treated of Architecture after the revival of the Roman style, we find expressions of contempt unsparingly lavished on that which for five centuries had been cultivated with so much ardour. The Italian writers stigmatize the Tedescan style as barbarous. In England, Sir Henry Wotton, speaking of the pointed arch, which is one of its distinguishing characteristics, says, that "from its weakness and want of beauty it ought to be abandoned to its inventors, the Goths and Lombards, with the other relics of a barbarous Age." And in Sir Christopher Wren's *Parentalia*, the Gothic Architecture is described as consisting of "an unreasonable thickness of walls, with clumsy buttresses and towers, and sharp-pointed arches; doors and other apertures without proportion; nonsensical insertion of various marbles impertinently placed; turrets and pinnacles thickly set with monkeys and chimeras:" it is added that "abundance of busy work and other incongruities dissipate and break the angles of the sight, and so confound it that one cannot consider with any steadiness where to begin or end; taking off from that noble air of grandeur, that bold and graceful manner, which the Ancients had so well and judiciously established."

Style of the ancient houses in Venice.

A peculiar disposition and style prevailed in the houses of the Nobility of Venice from an early period. In the lower part a grand and simple substruction rises from the water, and above this the façades are of various styles of Architecture, some resembling the Saracenic, others the works of a later Age. A hall extended from front to rear, quite through the building; on all the principal floors, and on each side of the hall, were the dwelling apartments. In the oldest buildings the centre of the façade was occupied by one or more tiers of balconies ornamented with small pillars and arches in various ways. The latter were either semicircular or pointed, and frequently were formed by curves of contrary flexure; sometimes in the same building were rows of intersecting semicircular and pointed arches, and within the intersections were trefoil ornaments. On the right and left of the centre of the façade were two windows on each floor, with a wide pier between them, and these windows always looked over a canal.

Ducal Palace.

The façade of the Palace of the Doge, which is one of the edifices built in the Saracenic manner, is composed of three stories: the lower one is an arcade consisting of eighteen simply pointed arches, springing from thick and dwarfish columns; above this is an open gallery, in front of which are thirty-six small pointed arches of contrary flexure, having the intrados cut in a trefoil shape, and there is an open quatrefoil inscribed in a circle in the spandrils. The height of these two tiers of arches is equal to about half the whole height of the building, and in the centre of the upper arcade is a large balcony having in front one pointed arch supported on columns with tabernacle-work above and pinnacles at the sides. Over this arch is an Attic, ornamented with sculpture and crowned by a statue. The whole façade to the right and left of the balcony is formed of masonry jointed diagonally, which gives it an appearance of trellis-work; and in this part, are six large windows with pointed heads. The cornice of the whole building is horizontal, and terminated by a battlement of open-work. Several buildings of a similar character exist at Venice; their style seems to be compounded of the Lombard, Moorish, and Tedescan-Gothic.

The Cathedral of St. Mary, at Florence.

The spirit which dictated the style of the Cathedrals at Pisa, Orvietta, and other places in Italy, continued to influence the artists of that Country till they returned to the Classic Architecture of the Ancients; and, considering those works as modified copies of the more ancient Basilican Churches, we conclude that the Roman Architecture, though once in a state of degradation, has been employed in that Country without interruption to the present time. But the Roman Architecture, travelling Northward, acquired, as we have observed, the Gothic character, and this subsequently was partially adopted in Italy. The building which seems to connect the Gothic style with the revived Roman, is the Cathedral of St. Mary, at Florence, which, in 1298, was begun by Arnulfo di Cambio da Colle, an Architect of that city; and though it, in some respects, resembles the older edifices, yet it bears marks of a genius rising above the prejudices of its Age and Nation.

The plan is that of a Latin cross, the whole length of which is 520 feet, and that of the transept 313 feet. The nave of the Church is divided longitudinally into three parts by magnificent arcades, supported on piers ornamented with Corinthian pilasters. At the extremity of the nave, are the communications between that part of the building and the transept; these are terminated above by three arches, of which the span of the central one is 58 feet. The interior of the body of the Church, at its intersection with the transept, is of an octagonal form, and its length and breadth between the opposite faces of the octagon are 140 feet. The wings of the transept and the extremity of the Church opposite to the nave are recesses in the form of half octagons on the plan, and the breadths between the opposite faces are each 58 feet; they are all open towards the interior of the Church; and each is covered by a semicupola springing from the walls of the octagon and ending in a point over the centre of a circle which would circumscribe the octagon if complete. The horizontal cornice from which the cupolas spring is 97 feet high above the pavement, and the vertex of each cupola is 43 feet above the level of the cornice.

Above the level of the vertices of these cupolas is built a wall of an octagonal form, 16 feet thick and 43 feet high, resting upon four massive piers and the tops of four intermediate arches about the central part of the Church; and in each of the eight faces of this wall is formed a circular window to give light to the interior. This wall is terminated by a horizontal cornice, and from it springs the grand dome, which is composed of eight faces rising from the sides of the tambour, and joined together in salient ridges, which if produced would meet in a point over the centre of the body of the Church. The span of the dome between the opposite faces of the octagon is 140 feet, and its vertical section presents a figure formed by two segments of circles meeting each other in a cusp at the vertex like a Gothic arch. The faces of the dome terminate at 280 feet above the pavement of the Church, or 116 feet above the cornice from which they spring; and at this elevation is constructed an octagonal lantern. 45 feet high, and 24 feet diameter between the opposite sides. Above the lantern is an octangular pyramid, or pergamena, surmounted by a ball and cross.

The dome is composed of two shells or vaults one within the other, and having an interval of about 5 feet between them; the thickness of the interior vault at bottom is 5 feet 6 inches, and at top 2 feet 1 inch; that of the exterior vault at bottom is 4 feet 3 inches, and at top little more than 1 foot. The radius of curvature of the interior surface of the inner vault is 120 feet, and the exterior surface of the other is described from nearly the same centre. Eight buttresses fortify the angles of the vault; and the voussoirs in the circumference of its base are connected by a chain of iron to prevent them from being thrust outwards by the lateral pressure of the courses above.

The arches in the interior of the Cathedral are of the pointed form, and the radius of each segment is equal to about two-thirds of the span of the aperture. On the capitals of the pilasters in the nave are pedestals which support another tier of Corinthian pilasters; and from blocks above the capitals of these proceed the cross-springers and ribs of the groined vaulting of the nave. Round the whole interior and exterior of the Church, on a level with the tops of the side arches of the nave, are galleries supported by brackets and protected by an elegant pierced parapet. The windows of the lower tier in the Church terminate above in pointed arches, and are divided by a slender column into two apertures with trefoil heads; on the exterior, each window is crowned by a small, rectilinear pediment, with a slender pinnacle at each extremity; and in the walls of the nave, above the aisles, is a row of circular perforations on each side of the Church.

The whole exterior of the edifice is ornamented with attached pilasters or piers, projecting but a little way from the wall; and their faces, as well as that of the wall between them, are covered with inlaid marbles of different colours, which destroy the grand effect the building would otherwise produce. The tops of the pilasters, about the exterior of the transept and Eastern end of the Church, are connected by semicircular arches. These render the style of the building something like that of the Italian Churches of the Xth and XIth centuries; while the pointed windows and trefoil ornaments identify it with the Gothic style of the North of Europe, and the pilasters in the interior indicate a connection with the Architecture of ancient Rome.

The Taste and judgment displayed in the construction won, for this building, the praise of one of the greatest masters of the Art, Michael Angelo himself; who considered it as the first modern edifice of its kind, and one which prepared the way for a return to the methods of the Ancients. The body of the Cathedral was erected under the direction of Arnolfo, and the dome was designed by the same artist; but the opposition he experienced from his contemporaries prevented him from executing it; and it was reserved for Brunelleschi, at a later period, to carry on that which his illustrious predecessor had begun. Arnulfo died in the year 1300, and the building remained as he left it during one hundred and twenty years; Brunelleschi superintended the work from the year 1420 till his death, in 1440; and during those twenty years the dome was carried up to the base of the lantern, by a particular contrivance which rendered a general centreing of carpentry unnecessary. No similar work, before constructed, was equal to this dome in size or magnificence; and if its span is measured diagonally between two of the opposite angles, it is greater even than that of St. Peter's at Rome. The lantern was not completed till 1456, and the Western façade of the building remains still in an unfinished state; a lamentable proof of the poverty or indifference of the citizens of Florence.

The choir is an octangular enclosure having its centre immediately under that of the dome. It is surrounded by a stylobata supporting a screen of Ionic columns and pilasters, with an entablature and balustrade above; and the whole height of the enclosure is 19 feet 6 inches. There are four entrances to the choir, at right angles to each other, and each is crowned by a semicircular archivolt without spandrils. This choir was built according to the designs of Brunelleschi, with some few modifications.

At the South-Western angle of the building stands the *Campanile*, a prismatic tower 268 feet high to the top of the parapet, and on a square plan, each side of which is 47 feet 9 inches long. It consists of five stories with groined ceilings; a flight of steps inside leads quite to the top, and the exterior is ornamented with pilasters in the same style as the Cathedral itself. The three lower stories are lighted by narrow rectangular windows; in the faces of the fourth story are two tiers of windows, each tier consisting of two lancet-headed apertures, divided, by a slender twisted pillar or mullion, into two parts, with trefoil heads. In each face of the upper story is a broad window with one general head in the form of a pointed arch; the window is divided by slender twisted pillars into three apertures, with trefoil heads formed within the intersections of semicircular arches, which spring from the pillars and from the sides of the window. Above the fifth stage, and surrounding the building, is a gallery supported by brackets and protected by a parapet. The tower was begun by Giotto, in 1334, and carried on by Taddeo Gaddi; it was to have been crowned by a pyramid or spire 95 feet high, but this was never executed.

After building the Cathedral of St. Mary, or, as it is generally called, the *Duomo*, at Florence, Brunelleschi built several Churches in the same city, in which he abandoned the pointed arch but preserved the general features of the Lombard edifices. The plan still had the form of a Latin cross, and, as in the Gothic Churches, the length and height of his buildings were considerable in proportion to their breadths. In the nave of the Church of San Lorenzo, he has placed Corinthian columns with isolated entablatures, and double semicircular archivolts springing from above them. The centre is crowned by a dome, the lower part of which has the form of a spherical zone; and, instead of a lantern, there is placed above this, a hemisphere of smaller dimensions. The Church of San Spirito is similar to that last mentioned; but at the intersection of the nave and transept are four great piers ornamented with pilasters, which carry a regular unbroken entablature over the arcades of the aisles. In this building are still retained some Gothic mouldings, but those in the entablatures resemble nearly the antique. Lastly, the Capella dei Pazzi, by the same Artist, indicates a still nearer approach to the Roman style: its plan is rectangular, and it has six columns in front; about the interior are pilasters supporting entablatures, and above is a hemispherical dome.

In the long period which elapsed between the fall of the Roman Empire and the time of Alberti or Brunelleschi, nothing is known of the domestic Architecture of the Italians; and we can only suppose that it arose from the forms of the ancient castellated edifices of the Country. We are, therefore, obliged to commence our account of it with a description of the Florentine Palaces, of which the oldest remaining were executed about the latter of the above-mentioned periods.

These ancient mansions consist generally of a range of buildings disposed on the four sides of a *cortile* or quadrangular area which they enclose. At the angles are square towers crowned by battlements and machicolations; and, as well as the buildings between them, divided into stories, with a bold horizontal cornice to each. In the lower story of the principal façade, are from one to three grand entrance gateways covered by semicircular arches; and the windows in each story are commonly of similar forms. A Palace for the Spada family, which was built in or before the time of Brunelleschi, seems to be the oldest example existing of those mansions which, in Italy, succeeded the fortified Palaces, and the first in which the Orders are employed; the badness of the proportions in those Orders shows how little, before this time, the antique examples had been studied.

Palazzo Pitti.

The Palace Pitti, at Florence, was designed, and the lower part of it was executed, by Brunelleschi, consequently it may serve as a specimen of the disposition and style of the mansions of Italy at the end of the XIVth and beginning of the XVth century. The plan of the central part is a long parallelogram; at each extremity of this is a wing projecting forward at right angles to the front, and behind the centre is a small *cortile*. The elevation of the front approaches the pyramidal form; being divided into three stories of equal height, of which the second story is less extended than the lower and the third less than the second; a fourth story was to have been added, and this also was to have been shorter than the story below it, but it has never been executed. Each of the three stories is rusticated, that is the joints of the masonry are marked by grooves; each also is crowned by a cornice supporting a gallery, in front of which is a balustrade of small Ionic columns; the windows are semicircular-headed, and the joints of the voussoirs are also marked by grooves; but in the lower story there is only a window under each alternate window of the story above. Each of the faces next to the court contains three Orders of Architecture one above another; of these the lower is Tuscan and the shafts of its columns are covered with horizontal flutings. The second Order is Ionic, with square blocks at intervals along the shafts; between the columns are semicircular-headed recesses containing windows surrounded by architraves, and having pilasters on the jambs. On the exterior of the architrave, under each window, is a projecting table supported by corbels, placed not under the pilasters, which would seem to be the most natural place, but under the vertical architraves. The windows are crowned by pediments. The upper Order, which is probably of later date than the rest, consists of Corinthian columns, having also blocks at intervals upon the shafts. Between the columns are recesses with horizontal lintels formed by voussoirs; within each of these is a semicircular-headed recess and a window crowned by a circular pediment. The whole building is of a colossal character, and like the rest of the Italian mansions of that day, looks rather like a Prison than a Palace.

Works of Alberti.

Leon Battista Alberti, who was for some time the contemporary of Brunelleschi, flourished in Italy during the first half of the XVth century, and executed several works in a style which approximates to that of the pure Roman; his best edifices are the Church of San Francesco, at Rimini, and that of Santa Maria Annunziata, at Florence. The latter is a circular building, 76 feet in diameter, and 63 feet high, with nine hemicylindrical alcoves, and crowned by a dome 38 feet high, rising from a tambour supported on a circular range of arches in the interior. On each side of the arches is a Corinthian pilaster with its entablature, above which are termini, and between these are square windows with pediments above. The Corinthian Order in this Church possesses a character of great purity, and the artist appears to have adopted the proportions of the antique more accurately than his predecessor.

St. Maria Annunziata.

Cathedral at Rimini.

The front of the Cathedral at Rimini was also executed by Alberti. This is adorned with four half-columns attached to the wall, and an entablature broken over each; in the centre is a grand doorway with a semicircular head, the archivolt of which springs from imposts projecting before the wall, but unsupported by columns or pilasters. Within the great doorway is a smaller one having a pediment above, which rises to the level of the foot of the arch over the other; and on each side is a semicircular-headed recess. According to a medal by Malatesta, there was to have been a segmental pediment extending over the whole façade, and the Church was to have been crowned by a dome, but neither of these intentions have been executed.

Attached to one side of the Cathedral is a *loggia* or covered arcade, which was built by the same artist: it consists of seven semicircular arches surrounded by archivolts, which rise from imposts on a range of piers 5 feet 10 inches wide, and 16 feet 2 inches high; and these stand on a podium 9 feet 7 inches high. The spans of the arches are 11 feet 7 inches; the spandrils between them are ornamented with wreaths, and the whole is crowned by a cornice, the mouldings of which resemble those of the Greek or Roman buildings.

Alberti is the first Architect who has written on his profession since the time of Vitruvius, at least he is the first whose Works have been preserved to our times. In X Books he treats of the origin of Architecture, which he supposes to have taken place in Asia; he explains the method of forming the foundations, and of building walls and arches in masonry; he gives general directions for designing Palaces, Basilicas, and other public and private edifices, and shows the manner of ornamenting their different members: he also treats of four Orders of Architecture, *viz.* the Doric, Ionic, Corinthian, and what he calls the Tuscan, which is that we usually designate the Composite Order. He makes the proportions of the parts of columns and their entablatures nearly the same as those assigned by Vitruvius; he forms the shaft cylindrical as far as three-sevenths of its height, from which place it diminishes up to the capital, and he gives a simple base to the columns of the Doric Order.

The artists of the Lombard School had made their arcades rise immediately from the capitals of columns; but Alberti observes that the ancient masters placed above the capital a projecting cornice on which the archivolt was made to rest; and this method was, by the example of Brunelleschi and himself, brought again into general use. Alberti moreover, very justly, prefers square piers to columns for the support of arches and vaults. The Rucellai Palace, executed at Florence by this artist, is one of the first in which pilasters are placed in front of each story; and this afterward became a general feature in the buildings of Italy.

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About the same time, the Architect, Orgagno, built a loggia adjoining the old Ducal Palace at Florence, the length of which is about 109 feet, and its depth 37 feet. The front consists of four octagonal piers with a pilaster on each face, supported by a podium; from the tops of the pilasters spring plain, semicircular arches, and the ceiling is formed by a groined vaulting, the ridges of which are ornamented by ribs rising from slender shafts in the rentrant angles formed between the pilasters. The *loggia* is crowned by a projecting machicolated parapet supported on brackets; the face of the parapet is pierced with quatrefoil apertures, and between the brackets a series of trefoil, cuspid arches is formed in front. This fabric presents a striking and graceful appearance, and its proportions are good, but its effect is rather injured by too great a height above the crowns of the arches.

Succession of Italian Architects from Brunelleschi to Scamozzi.

From the time of Brunelleschi till the commencement of the XVIIth century, there followed each other, in Italy, several celebrated Architects; who having studied the remains of the works of their ancestors, with which the Country abounds, formed the style which, by subsequent improvements, is become that which now prevails in every part of Europe.

Alberti survived Brunelleschi about thirty years, and both of these artists were employed in various Ecclesiastical buildings at Florence, Mantua, or Rome. Bramante d'Urbino and Raphaele d'Urbino were contemporaries, and the immediate successors of Alberti; these built or gave designs for several Palaces for the Italian Nobility; and the former has the glory of having begun the building of St. Peter's Church, at Rome. Peruzzi followed, who, besides sundry other works, made alterations in the original design for that edifice. San Michaeli built several Palaces and Churches within a few years after the time of the last-mentioned Architect; and about the same time lived Michael Angelo Buonarotti, the most celebrated Architect and Painter of his day, and under whose direction a considerable part of St. Peter's Church was carried on. After these may be mentioned the names of Sansovino and Julio Romano; of Serlio, who wrote VII Books on Architecture, and was the first to measure and describe correctly the ancient edifices of Italy; and of San Gallo and Barozzi, commonly called Vignola, who were either contemporaries or immediate successors of each other. Next in order of time comes Palladio, who distinguished himself particularly, not only by his designs and buildings, but by the Work which he has left on Architecture, and which is indispensable to every one who would acquaint himself not only with the principles of the Italian but also with those of the Roman Art. We may, in the last place, mention Scamozzi, who died

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in 1616, and Bertotti, who took the same name, and published a collection of Palladio's designs, which is deservedly held in estimation.

The Greco-Italico style, which had been improved by Brunelleschi and Alberti, was, by Bramante and his immediate successors, made to approach still nearer to the style of ancient Rome; this modification acquired a certain degree of perfection in the latter part of the XVth and during the XVIth century; and from the merit which it displays at a time when Architecture in other parts of Europe was at a very low ebb, rather than from any peculiarities it exhibits, it has obtained among artists the distinction of the *Cinque-cento style*, from the number of hundreds in the dates of most of the works. Palladio subsequently improved it by a more strict adherence to the principles of the ancient Roman Architecture; and by the merit of the works he has executed, in a style which he made his own, he has rendered the Architecture of Italy that of all the rest of Europe.

CHAPTER II.

The Architecture of Italy during the XVth and XVIth Centuries.

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The Palazzo Giraud, at Rome, was executed by Bramante about the middle of the XVth century, and may be classed with those which are designated as being of the *cinque-cento* style. It consists of a range of buildings disposed about a quadrangle, 249 feet long, and 190 feet wide, and the entrance is by a vestibule in the middle of one of the shorter sides. This, which is 47 feet long and 34 feet wide, is divided into three parts longitudinally by two rows of columns, and it leads into a square court, 89 feet long in each direction; the latter is surrounded by an interior arcade, about 20 feet wide, which is covered by a groined vaulting, and the faces of the piers next to the court are ornamented with half-columns. At the extremity of the court, opposite the entrance, is a passage, 26 feet long and 15 feet wide, the sides of which are adorned with pilasters and niches. This leads to the rear vestibule, which is 53 feet long in the direction of the short side of the building, and 21 feet wide, and the extremities of its length are terminated by hemicylindrical niches.

The front elevation exhibits three stories, all of which are rusticated; in the lower part of the ground-story the joints of the masonry are marked by horizontal and vertical grooves, and in the upper part by horizontal grooves only; in the centre is a semicircular-headed doorway with a horizontal cornice above, and on each side are three square windows. In the lower part of the second story is a plain podium, and above this, the joints of the masonry are marked by horizontal and vertical grooves; a row of seven semicircular-headed windows is contained in this story, with horizontal cornices above them; the archivolts rest on pilasters, and the spandrils are ornamented with sculpture representing vases and stems of plants. Between the windows, are coupled pilasters of an Order resembling the Corinthian, with Attic bases on high plinths, under which the podium is broken and projects so as to give it the appearance of a line of pedestals connected by walls; and above the pilasters is a simple entablature. In the third story there are coupled Corinthian pilasters, with Tuscan bases over those in the second story; these also stand on high plinths placed above the projections of the podium; and between the pairs of pilasters, are two tiers of windows, the lower rectangular, and the upper having semicircular heads. These pilasters are crowned by the entablature of the building, the frize of which is occupied by blocks for the support of the cornice. The roof is formed with sloping sides, and is covered by hollow tiles. The proportions of the pilasters are good, but they would now be considered as having hardly sufficient relief from the wall.

Cancellaria, at Rome.

The front of the Cancellaria, at Rome, also executed by Bramante, is in the same style, with some few differences. The lower story contains merely a row of plain semicircular-headed windows; the windows of the second story are placed low, and above each is a small circular recess with a flower in its centre; those of the upper story are of a rectangular form with cornices above, and are cut through the podium; over these are small windows with semicircular heads inscribed in plain rectangles. The two upper stories are ornamented with pilasters of the Corinthian Order, disposed in pairs, but those in each pair are at a greater distance from each other than coupled columns or pilasters usually are. At each angle of the building a small projection of the façade takes place, so that it has the appearance of being flanked by towers; and in the breadth of the projection are contained four pilasters having the same dimensions and intervals as those on the other part of the façade.

Bramante constructed several other buildings, also, among which is the Church of San Pietro in Montorio, a circular edifice, considered as one of the first specimens of the regular Architecture of that day. This celebrated Architect died in the year 1514.

Palazzo Strozzi.

In 1454, that is during the life of Bramante, the Strozzi Palace, at Florence, was built by Benedetto da Majano and Pollajuolo, in a style which resembles that of Bramante, but partaking in some degree of the character of the old Lombard Architecture. The façade is rusticated from top to bottom, by vertical and horizontal grooves; it is divided into three stories, separated from each other by frizes, ornamented with dentels; and the whole is crowned by a plain frize, and a bold cornice, in which are both dentels and modillons. In the centre of the lower story is a semicircular-headed doorway, and on each side are three rectangular windows; the windows of the upper story are semicircular-headed, with voussoirs, the joints of which are marked by grooves; each window has half-columns attached to its sides, and a column in the middle, all of a kind resembling those in the Norman edifices. The two apertures of each window are crowned by semicircular heads, which are circumscribed by the outer semicircle; and the spandril between the three curves is occupied by a patera.

Peruzzi.
Palazzo Farnese.

The small Farnese Palace, at Rome, is a splendid example of the talents of Peruzzi, who was contemporary with Bramante, and survived him twelve years. The plan is rectangular; and, attached to the wall of the ground-floor is a range of Doric pilasters, which surround the building except where they are interrupted in front by a superb *loggia* or portico, composed of five arches, the spans of which are equal to the interval between every two pilasters. A similar range of Doric pilasters, between the windows, surrounds the building on the story above the ground-floor, and these are remarkable for being more massive than those in the lower range. Between the two stories are a *mezzanine* or an intermediate story with small windows in front, and the frize which surrounds the upper story is ornamented with festoons supported by Genii and candelabra. The portico above-mentioned gives variety to the edifice without destroying the unity of the composition; and the profiles of the mouldings are remarkably elegant.

Palazzo Massimi.

The Massimi Palace, at Rome, is the last and best work of this Architect. It is on an irregular plan, and in a confined situation, which prevents the upper part of the building from being conveniently seen by a spectator in the street; and on this account the artist has judiciously given it less ornament than the part below. The façade is rusticated, and divided into four stories; in the lowest is a superb *loggia*, the plan of which is in the form of a segment of a circle, convex towards the street; its ceiling is highly ornamented, and there is a hemicylindrical recess at each end; in front are two pairs of coupled columns, besides a coupled column and pilaster at each extremity. The columns are of the Doric Order, elegantly proportioned, and crowned by an entablature without triglyphs or mutules; they have Attic bases, and the profiles of the ovolos in the capitals, instead of being quadrants, are flat segments of circles. From the *loggia* is an entrance through a vaulted corridor into the *cortile*. In the lower part of the second story is a plain podium, over which are seven rectangular windows with horizontal cornices above; the windows in the two upper stories are square and without ornament, and the building is crowned by a horizontal cornice supported by modillons.

The details of this edifice are correctly antique, and every part indicates a refinement of taste far beyond that displayed in any other work of the Age. The interiors of the apartments are highly finished; some of the ornaments resemble those on the Greek Temples, and others are like those represented in the paintings at Herculaneum and in the Baths of Titus. In one apartment is a fire-place, ornamented with fluted pilasters on each side, accompanied by cossoles of equal height with the pilasters; above these is an entablature with swelled frize, and over it a sort of sarcophagus ornament.

Palazzo Medici or Riccardi.

The last of the Florentine edifices of the kind we are now describing is the Riccardi Palace, which was executed by Cosmo the Great, and nearly resembles the Strozzi Palace, built probably a hundred years before it. Its façade is divided into three stories, of which the lowest consists of blocks in irregular courses, some projecting before others, and in it is a circular-headed doorway. The second story is rusticated, but faced with wrought stone, and in it are seventeen windows almost close together, with semicircular heads; each window is divided into two lights by a column, and these have also semicircular heads. A high, plain face presents itself above the windows of this story, and at the top is a dentel band. Above this is the third story, of plain stone-work, with seventeen windows similar to those in the story below; and the whole is crowned by a bold and beautiful cornice resembling those of the ancient Roman Architecture.

Venetian edifices of the XVth and XVIth centuries.

In the buildings at Venice is exhibited an adherence to the Lombard style of Architecture after it had been every where else abandoned. The Palazzo Camerlinghi seems to have been one of the latest works of that School. It is divided into three stories, with a double semicircular-headed window in the centre of each, and on either side of it a single window of the same kind; the arched heads of the windows rest on panelled pilasters, and the extremities of the building are ornamented with pilasters of a similar kind. To the same class may be referred the façade of the School of St. Mark, which was built by Martin Lombardi, but at what time is uncertain. This is divided into two stories, ornamented with Corinthian pilasters carrying an entablature which is broken over each; between these, on the second tier, are semicircular-headed windows, crowned by segmental or triangular pediments: in the lower story is a semicircular-headed arch supported by two columns; and on each side of the arch between the pilasters of this story are panels filled with sculpture in bas-relief, representing Architectural subjects in perspective. The whole front is crowned by semicircular pediments of different heights, and surmounted by scrolls and statues.

The Church of San Salvador also partakes in some measure of the Lombard character. This is in the form of a Latin cross, and has three cupolas in its length; in the interior the lower Order is ornamented with panelled Corinthian pilasters supporting an entablature; above which is a *mezzanine* story with semicircular arches in front; and from between them, spring pendentives which are crowned by the domes.

Sansovino.

But the edifices of Venice at length partook of that change in the general Architecture of Italy which arose from the study of the antique examples, and the works of Sansovino contributed materially to the establishment of the new style in that city. The Procuratie vecchie, which constitutes one side of the Grand Piazza of St. Mark, is an edifice probably of the XVth century, and forms a good specimen of the style of that Age. Its façade is divided into three tiers of arcades of semicircular forms, and those of the lowest range are supported on piers; the two upper tiers rest on columns, and each arch is only half as broad as one of those in the lower tier, so that two of them stand over one of the latter; between the tiers are plain podia, and the building is crowned by an entablature with a high frize in which are circular apertures. In the small Piazza adjoining the former, is the Libreria vecchia, a work of Sansovino; the façade of this building consists of two tiers of arcades, the lower ornamented with columns of the Doric, and the upper with columns of the Ionic Order; each range of columns supports a heavy, unbroken entablature with a balustrade; the Ionic columns stand on pedestals; and in order to diminish the massiveness of the upper entablature it is perforated by small apertures, between which are festoons of flowers supported by Cupids. In the grand Piazza, and at right angles to the Libreria vecchia, is the Procuratie nuove, in the façade of which are three Orders, of which the two lower are continuations of those in the other building, and were executed by the same artist; but the upper one, which is of the Corinthian Order, was afterward added by Scamozzi. Sansovino was born nearly at the same time as Peruzzi, but he survived the latter 34 years, having attained the advanced age of 81 years; he died in 1570.

San Michaeli.

San Michaeli, though born five years after Sansovino, died eleven years before him. He distinguished himself by various works with which he adorned Verona, and of his mansions the best is, probably, the Palazzo Pompei; in the façade of this building there are two stories, of which the lower is rusticated, and contains a doorway and windows with semicircular heads, over which is a balustrade; the upper story contains also windows of a similar form, but the piers between them are ornamented with eight attached, three-quarter columns of the Doric Order, which support a bold and continuous entablature.

The frontispiece of the Piazza dei Signori, at Verona, another of his works, consists of a semicircular arch springing from imposts; on each side are two fluted Ionic half-columns with Corinthian bases. The entablature is broken over the two extreme columns, and the part over the arch and the adjacent columns is crowned by a pediment. The same artist built the Castello St. Andrea, on an island at Venice, to form a sort of water-gate to the fortifications. It consists of three arches, having half-columns attached to the piers, and at each extremity is a column and pilaster coupled, of which the latter forms the quoin of the building. The columns as well as the piers are rusticated, and the former support a well-proportioned Doric entablature with triglyphs in its frize. A curtain, which is connected with the arcade, is crowned by a parapet, and has casemates on a level with the water, which comes up to the gate.

lazzo di by Julio mano.

The Palazzo di T, so named from its shape, at Mantua, may be considered a fair specimen of the works of Julio Romano, who lived during the first half of the XVIth century. Its façade is divided into two stories, of which the lower is merely a rusticated basement with semicircular-headed arches. In the centre of the upper or principal story, is a portico containing four groups, each consisting of four columns, two in front and two in depth; these support imposts from which spring three semicircular arches, and above these, is a general pediment to the portico. In each wing of the building are three rectangular recesses, of which the one nearest the portico on each side contains four columns, the next on each side three; and the last on each side two; the interval of the centre columns in the recesses nearest the portico is covered by a semicircular arch, and above these is a general horizontal entablature to the whole building.

The grouped columns give to this edifice a singularity to appearance, which is increased by an instance of depraved taste in making some parts of the Doric entablature lower than the others; in consequence of which it appears as if part of the edifice had sunk, and thus the perception of stability, so essential to architectonic beauty and fitness, is wanting.

bedral Iantua.

The interior of the Cathedral of Mantua was also executed by this Architect. It is divided into seven aisles, separated from each other by columns; the central and the two outer divisions are covered by flat roofs, and the others by hemicylindrical vaults. The central division is separated from that next to it on each side by a range of fluted Corinthian columns, supporting an entablature; above this, is a tier of pilasters, carrying also an entablature, which, as well as the former, is unbroken, and the whole is crowned by an elegant dome.

ael do narotti.

As specimens of the Taste of Michael Angelo Buonarotti in Architecture may be mentioned, first, the Church of Santa Maria degli Angeli, which he formed in the principal hall of the Baths of Dioclesian, at Rome, and which is remarkable for its grandeur and simplicity. The entrance is in the centre of one of the long sides, through the ancient circular vestibule; and both those sides, which were originally open, are filled up and adorned with Composite columns, extending from the pavement to the springing of the groined vaulting; some of these are antiques, and the others have been formed in imitation of them. The Capella dei Depositi, at Florence, is a work of the same artist; this is a square building with a hemispherical dome supported on pendentives.

Campidoglio.

The present Campidoglio, at Rome, the site of the ancient Capitol, is occupied by buildings for which M. Angelo gave the general plan, and some of which are supposed to have been executed under his direction. The buildings are disposed on three sides of a trapezoid about a platform, to which there is an ascent by an inclined plane, about 177 feet long, 26 feet wide at the foot, and 37 feet wide at the top; on each side of the ascent is a balustrade, and at the top are two pedestals supporting statues of Castor and Pollux; on the right and left of these is a balustrade, with pedestals at intervals along it, containing statues and trophies. The platform is 250 feet long, 134 feet wide at the end next to the inclined plane, and 182 feet wide at the opposite end, and is elevated about 40 feet above the level of the neighbouring streets. In the centre, is an equestrian statue of Marcus Aurelius in antique bronze. On each side of the platform is a grand Museum, and in front is the Palace of the Senator of Rome. The last-named building, which there is great reason to believe to be the work of M. Angelo, is of a rectangular form, and its façade is decorated with a majestic Order of attached Corinthian pilasters rising from a lofty basement, and supporting an entablature which is crowned by a balustrade. This façade is remarkable for its purity and simplicity, and appears to advantage when contrasted with those of the neighbouring buildings, which are also ornamented with Corinthian pilasters and half-columns, but mounted on pedestals. The height of the Order above the basement is divided into two stories; the ascent to the lower is by steps on the right and left hand, which meet in the centre where the doorway is situated; and below this is a fountain. Between the central building and the left-hand Museum, is an ascent by a flight of steps, about 100 feet long and 48 feet 6 inches broad, to an arcade forming the side entrance to the Church of Ara Cœli. On the right hand a similar flight leads to private dwellings on the site of the Tarpeian rock. On the right and left hand of the Senator's Palace is a descent by a flight of steps leading to the great Forum, and the former flight is supposed to coincide with the ancient *Clivus Capitolinus*.

Palazzo Farnese, by San Gallo and Vignola.

The great Farnese Palace, at Rome, which was built by San Gallo and Vignola, both of whom lived during the XVIth century, is a rectangular building 236 feet long, 170 feet wide, and 177 feet high from the ground to the top of the cornice; and its general plan resembles that of the Palazzo Giraud before mentioned. The principal façade is one of the most majestic in the world, presenting to the eye one unbroken mass, which is crowned by a noble frize and cornice; it consists of three stories, which are separated by horizontal bands filled with sculptured foliage. The windows of the lowest story are rectangular, with simple architraves, and surmounted by horizontal cornices supported by corbels; those in the second story are also rectangular, but those in the upper story have semicircular heads, and the windows in both these tiers are crowned by pediments, the entablatures of which are supported by columns. The doorway has a semicircular head with voussoirs; the angles of the building and the wall between the doorway and nearest windows are rusticated.

The faces of the building within the *cortile* contain three Orders of columns, the lowest Doric and the second Ionic; both of these support entablatures, and between the columns are semicircular arches springing from imposts on the piers; the upper Order is Corinthian, and in the intervals of its columns are rectangular windows. Between the second and upper stories are *mezzanine*, with small square windows towards the court.

The Cathedral of St. Peter.

We conclude our account of the Italian edifices of this Age with a description of the Cathedral of St. Peter, at Rome, which may fairly be considered as the most magnificent building in the World, and the noblest monument of the science of the Italian Architects. This edifice was built on the site of the Church which had been dedicated by Constantine to the same Apostle; it was begun during the Pontificate of Julius I.; was carried on by contributions from all Europe; was the subject of anxious solicitude to twelve succeeding Popes; occupied the talents of as many Architects during more than one hundred years; and it now remains the boast of the Christian World.

The interior has the form of a Latin cross, the whole length of which, from East to West, is 735 feet, and its breadth 510 feet. The interior breadth of each arm of the cross is 75 feet, except of that which forms the nave, which is 90 feet. At the intersection of the arms are the four great piers on which the dome is supported. Four aisles, each 50 feet broad, at right angles to each other, and intersecting the four arms of the cross also at right angles, separate those piers from the exterior walls of the Church.

The piers support four semicircular arches, the crowns of which are at the height of 200 feet from the pavement, and on them is built a cylindrical wall, 70 feet high, and 150 feet in diameter internally; this is perforated by windows with rectilinear or circular pediment heads both on the interior and exterior; between which are coupled Corinthian columns carrying an entablature broken over each pair of columns. The top of the wall rises 20 feet above the entablature of the columns, and from it springs the great dome; this is double, consisting of two shells, of which that on the exterior is of a spheroidal form, 170 feet in diameter externally, and 100 feet high from its foot to the level of the base of the lantern. The interior dome is also spheroidal, but flatter than the other, its internal diameter being 140 feet, and its height 77 feet; and these domes are connected by sixteen ribs of masonry formed in vertical planes. The lantern is 40 feet high, and above it is a small spire terminating in a ball and cross. Three tiers of windows are formed about the circumference of the outer dome, and the extrados of the other is worked in steps for the convenience of ascent. The height of the building from the pavement to the top of the lantern is 440 feet.

Along the whole of the Western extremity of the Church is a porch 50 feet wide, separated from the nave by a wall in which are five doorways, opposite to as many others in the façade. The nave is divided into three parts or aisles by massive piers ornamented with pilasters, and supporting arches in the direction of the length of the building. A Chapel is formed on each side of the nave, where the latter joins the transept; they are rectangular on the plan, and covered by spheroidal domes similar to the principal one. These domes stand upon octagonal walls ornamented with pilasters; their height from the pavement to the base of the lantern is 250 feet, and their interior diameter 50 feet.

The Western extremity of the Church presents a façade adorned with half-columns and pilasters; its whole length is 425 feet, and its height 125 feet from the pavement to the top of the entablature of the columns; within this height are included two stories, and above the entablature is another story 50 feet high, which is crowned by a balustrade. Over the four central columns is a pediment and the entablature on each side is broken vertically into three parts. Between those columns is the principal entrance which has a horizontal head; on each side of it is a small one with a semicircular head, and further to the right and left are two other grand entrances similar to that in the centre. At the extremities of the porch are two square wings projecting beyond the side walls of the building and crowned by its general entablature, and in each side of these wings is a magnificent doorway with a semicircular head.

Before this façade of the Church, is a trapezoidal area 400 feet long, and having its greatest breadth equal to that of the whole front; this is bounded on each side by a corridor, from the Western extremity of which proceeds a semicircular colonnade, and these two colonnades form part of the periphery of an oval area, 650 feet long from North to South, and 500 feet wide from East to West.

Under the centre of the dome is a magnificent *baldachino*, or canopy, of a square form, executed in bronze, and 120 feet high, covering the Grand altar. The upper part is supported by four columns of the Composite Order resting on marble pedestals; the columns are formed so as to appear twisted, and are channelled in spiral grooves as far from the bases as one-third of their height; the remainder of the shaft is ornamented with laurel leaves and figures of boys, and above the canopy are four great figures of angels standing over the columns.

According to the original design of Bramante, the plan of the whole Cathedral was to be in the form of a Latin cross, and as such he commenced the building, in 1506; after his death, Jocondo, Julian San Gallo, and Raphael were employed in increasing the magnitude of the piers which were to support the dome: subsequently it was proposed by Peruzzi, Antonio San Gallo, and Michael Angelo, to change the form of the plan for that of a Greek cross, and under the direction of the two former, the body of the Church was completed, and the dome commenced; the latter was chiefly employed in embellishing the dome with paintings. Sundry additions were made by Ligorio and Vignola, and, in 1590, the dome was completed by Fontana. Twenty years afterwards the nave and Western façade were built by Carlo Moderna; and the building, which may now be said to have been finished, again assumed the form of a Latin cross. The colonnades were built by Bernini, in 1721, that is, about a hundred years afterward.

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The passion for dividing large masses into an infinite number of small parts, and an inattention to the principles of sound Taste which require, in a work intended to inspire sublime emotions, that with its magnitude it should possess a certain simplicity of form, are both remarkably exhibited in this splendid edifice. The exterior and interior surfaces of the walls have so many vertical divisions, and are so covered by columns and pilasters, as to form innumerable angles which distract the attention of the spectator, and impede the conception of the general plan of the building.

The haste with which some parts of the walls were erected prevented the Architects from taking sufficient pains to secure their stability; from want of attention to the foundation, and from the unequal settling of the masonry, several considerable fractures soon made their appearance; the repair of which has long exercised the ingenuity of the Italian artists; and to prevent the dome from giving way by its lateral thrust towards the exterior, Van Vitelli, in 1743, caused it to be surrounded by four hoops or chains of iron imbedded in the masonry.

The impression made on the mind of a spectator on entering St. Peter's Church is, that its apparent magnitude is less than its dimensions seem to indicate; the cause of which deception, according to Montucla, is the small number of principal parts into which the Church is divided, and the great magnitude of the ornaments, particularly the figures, which serve as appendages to those parts. And the same Writer observes, in his *Philosophical Recreations*, that if the number of aisles in the nave had been greater than three, and the arches supported on groups of columns, instead of piers, the edifice would have appeared much larger. The effect which should be produced by a dome of such magnitude is here also considerably diminished; in the interior, because it is not seen till the spectator has passed the nave, which causes it to appear a subordinate part of the building; and on the exterior, by the great projection of the body of the Church, which prevents the spectator from getting a good view of it.

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The Architecture of Italy during the XIVth and early part of the XVth century is chiefly exhibited in the Palatial buildings which adorn its cities. At first, plain and massive, like fortresses, they subsequently acquired a great degree of lightness and elegance. The mansion of an Italian Nobleman consisted of a suite of buildings surrounding an open *cortile*, a disposition rendered necessary by the impossibility of extending the whole building in a line where, as in cities, frontage is scarce. The edifice was divided into three or more stories, and occasionally into two; the façade of the lower story was generally a rusticated wall pierced by arches or by windows with horizontal or semicircular heads; the piers were sometimes strengthened or adorned with three-quarter columns attached to their fronts, and having their shafts apparently interrupted, at intervals, by cubical blocks of masonry representing, in an unwrought state, parts of the mass of stone from whence the column is supposed to have been formed. Sometimes the upper stories are also rusticated and decorated with columns similar to those below; but occasionally the Ionic and Corinthian Orders are employed over a rustic basement without columns; in which case those above present by their delicacy an unnatural contrast with the style of the lower part of the façade. Horizontal entablatures, often loaded with heavy ornaments, divide the stories, and crown the whole edifice; the height of the architrave of the upper Order seems to have been made proportional to that of the Order itself; but the frize and cornice proportional to the whole building considered as an Order; and this was, perhaps, intended to enable the artist to give that great projection and consequent boldness to the cornices which are so much admired in the Italian edifices. In the same Age we find a frequent employment of the *mezzanine* stories, or suites of apartments of low elevation between two principal stories; a disposition which afterward became very common in Italy, and extended thence to other parts of Europe, where it is still practised; and though the good effect of the tier of small windows in a façade has been questioned, it must be admitted that in some cases it adds greatly to the beauty of the elevation; such apartments have, moreover, the merit of great convenience in the interior of a building.

The rustication of the masonry conveys an idea of great strength, with a degree of rudeness not inappropriate to the substructure of a building; but in the works of this Age it is carried too far, inasmuch as we frequently find the joints of the most slender piers and of the columns, even those of the delicate Ionic Order, marked in the same way, which not only weakens the shafts, but takes away the beauty arising from the view of their smooth surfaces.

In the public edifices, the style of Italian Architecture during the XVIth century seems to have been borrowed from that of the works executed during the later period of the Roman Empire, particularly, it bears some resemblance to the ornamental parts of the edifices at Spalatro and Balbec. The Porta di Venezia, at Padua, may serve as an example. This is a semicircular gate with coupled columns on each side resembling those of the Corinthian Order, with Attic bases; each pair stands on a common pedestal, and these are supported on consoles. At a distance from these and on each side of the arch is another pair of coupled columns, and the interval between each pair is occupied by a semicircular niche with a pilaster on each side. From the wall behind the columns projects a pilaster, the breadth of which is equal to that of the two columns; in the face of this pilaster, is a broad panel; and at the top, the angles of the pilaster are ornamented with foliage like that in the capitals of the columns.

In the façades of the Churches erected in this Age are generally two porticos or tiers of columns one above another; and the upper tier is crowned by a pediment: the lower portico is extended on each side beyond that above, on account of the side aisles, the roofs of which are not so high as that of the central division of the nave, and each flank of the upper portico is sometimes supported by a great scroll or volute, in a plane parallel to the face of the building; this must have been intended to serve as a buttress, but it forms an absurd member when applied to a work executed in masonry. A capricious taste is often exhibited in Churches of this period mingled with that which characterises the best works of a later day. In the Capella Pelegrini, at Verona, which is a cylindrical building covered by a hemispherical dome, are columns disfigured by spiral flutings, yet the interior of the cupola and the Order which carries it are two of the most beautiful things of their kind in existence. The upper portico of the Church of Santa Maria in via lata, at Rome, consists of four Composite columns supporting a pediment, the horizontal entablature of which is interrupted over the two middle columns, and a semicircular arch is formed cutting the tympanum of the pediment; yet the columns of both the lower and upper portico are well proportioned, and a high podium between the Orders gives to the façade a fine effect. The Church del' Carignano, at Genoa, exhibits an example of a well-arranged plan, while the proportions of the Order employed on the exterior are bad. The plan has the figure of a vast Greek cross with the principal dome over the intersection; in each rentrant space, between the arms, is another cross, connecting those arms, so as to permit a vista quite through; and the centre of each of these crosses forms a Chapel which is covered by a small dome. The ancient houses of the Genoese Nobility had their fronts ornamented with parallel stripes of black and white marble, alternately disposed; but most of these have disappeared, and the more modern Palaces are faced with stucco, which is frequently painted in fresco: some of the Churches of Genoa, however, retain the different-coloured stripes, and prove how much this strange kind of embellishment must have been once esteemed in that part of Italy.

Italian Altars.

All the riches of Art have been displayed in the Altars of the Italian Churches; according to Milizia, each is a mountain of columns supporting only pediments of fantastical forms, which serve but to harbour dust and spiders' webs; every sort of precious marble is employed and covered with gilding, but the Architecture and the ornaments are equally devoid of taste. This reproach is applicable even to those Altars which are disposed in recesses in the interior of the Church; when placed under the dome or in the choir they are further attended with the disadvantage of interrupting the view and diminishing the apparent length of the edifice, and this is particularly the case with the High Altar in St. Peter's Church, which we have already described. But though these observations apply to the generality of the Italian Altars, it must be admitted that there are some which possess a certain degree of elegance and classical taste, and among them may be named those which Palladio has disposed along the sides of the Church of the Redeemer, at Venice.

Tombs.

The monumental edifices of Italy which have been executed since the revival of Roman Architecture are deserving of notice in this place. At Bologna is a curious one consisting of nine columns raised on a square plan and carrying a floor, on each side of which are pillars supporting three Gothic arches, and the whole is crowned by a pyramidal spire: at each of the four angles of the wall is a Roman oreille, and within the space enclosed by the arches was the sarcophagus. In the *Monumenti della Toscana* are given delineations and descriptions of Tombs, chiefly found in Rome, Venice, and Tuscany, which appear to be works executed in the XVIth century: they consist of a sarcophagus on which is a recumbent statue of the deceased, and about this are columns or pilasters supporting an ornamented entablature, above which is a semicircular or semielliptical panel surrounded by a scroll and containing a sculptured representation of the infant Jesus in the arms of his mother. The tomb of the Scaligeri, erected in the XVIIth century, at Verona, is probably an imitation of some of those which were executed in the preceding Age: it consists of a hexagonal floor supported by piers without arches and carrying the sarcophagus; above this is a rich, open canopy of a hexagonal form, with pointed arches supported on twisted columns, and the whole is crowned by a frustum of a pyramid supporting an equestrian statue, and ornamented with tabernacles at the angles. Round the base, is a low hexagonal wall with tabernacles at the angles, supported by square piers.

Fountains.

The Fountains of Rome exhibit some grand designs representing the façades of mansions or Triumphal Arches, and the water, gushing through apertures in the buildings, is received in a reservoir at the foot. The façade of the Fountain of Trevi consists of a centre and two wings ornamented with Corinthian columns bearing an entablature and an Attic above; the whole stands upon a plain basement, in front of which is a mass of rock-work, and over this the water pours from under a statue of Neptune in a recess formed in the centre of the façade; the reservoir below is of white marble, and there is a descent to the water by a flight of steps of the same material. Upon the rock-work are figures indifferently sculptured, and the rude forms of the materials at the foot of the building does not accord with the delicacy of the Corinthian Order above. The Fountains dell' aqua Felice and dell' aqua Paolo, built or restored by Dominico and Giovanne Fontana, have each, in front, three semicircular-headed arches between Ionic columns which support an entablature and two Attics crowned by a segmental pediment; the first of these is situated on the Viminal hill, and is supplied by the Aqua Claudia, the other crowns the Janiculum. Both elevations are meagre and ill adapted to their destinations. The Castel dell' aqua Julia, near Rome, is a more appropriate edifice; the front is ornamented with pilasters, bearing an entablature, and between them are three hemicylindrical recesses; the two extreme are occupied by trophies, and the third contains a statue on a pedestal; above the entablature is an Attic with an inscription, and the whole stands on a lofty plain basement, in which are numerous small apertures for the passage of the water to the reservoir in front.

The five Orders of Architecture modified by Vignola.

Vignola, in his *Treatise on Architecture*, has modified the Roman Orders, and given them a considerable degree of lightness. His Tuscan column is 7.5 diameters high, including the base and capital, both of which resemble those in the Vitruvian example; the diminution of the shaft is one-sixth of the lower diameter, or the difference of the semidiameters is $\frac{1}{78}$ of the length of the shaft. The height of the architrave is 0.417 diameter, of the frize is 0.583 diameter, and of the cornice is 0.667 diameter, consequently, the height of the whole entablature is equal to $\frac{1}{4.5}$ of the height of the column. The projection of the corona from the axis of the column is equal to one diameter.

He makes the height of his Doric column equal to eight diameters, including the base and capital, each of which he makes equal to half a diameter. The base, in some examples, consists of a plinth and torus, and in others is of the Attic kind; the capital consists of an abacus and an ovolo, the profile of which is in the form of a quadrant of a circle; this member is either plain or sculptured, and below it are fillets and a hypotrachelion, which is separated from the shaft by an astragal. The diminution of the shaft is equal to one-sixth of the lower diameter, and, consequently, the difference of the semidiameters is $\frac{1}{84}$ of the length of the shaft. The height of the architrave is made equal to half a diameter, and the frize and cornice each equal to three-quarters of a diameter; consequently, the whole entablature is one-quarter of the height of the column. The centres of his triglyphs correspond with the axes of the columns; the metopes are square and ornamented with ox-heads or trophies. His cornices have great projection, but in this member, the examples he has given differ from each other; under the corona of some are high mutules with horizontal soffits, and guttæ below; others are without mutules, but have a row of dentels under the corona. In the ancient Greek or Roman examples we find the Doric columns are without bases; but from the time of the revival of the Roman style Architects seem to have considered a base as necessary for this Order as for the others; and they have compared a column without one to a man without feet.

Vignola's Ionic column is made nine diameters high, of which the base and capital are each equal to half a diameter, considering the height of the capital to extend

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from the bottom of the volutes to the top of the abacus. The base is similar to that given by Vitruvius; the volutes in the capital are small and their faces are in a plane parallel to that of the entablature; which was also the case with those given by Alberti and Serlio. The diminution of the shaft is one-sixth of the lower diameter, hence the difference of the semidiameters is $\frac{1}{96}$ of the length of the shaft. The height of the architrave is equal to 0.625 diameter, and is divided horizontally into three faciæ, of which the lower one is vertically over the upper part of the face of the shaft; and the others project before it. The height of the frize is 0.75 diameter, and this member is highly ornamented with sculpture. That of the cornice is 0.875 diameter, and in the face is a row of dentels. The whole height of the entablature is equal to one-quarter of that of the column. The effect of this Order is grand, but several parts are liable to objection; the base appears incapable of supporting the weight of the column, the volutes are too small, and the corona is deficient in height.

We have said that in order to avoid the bad effect arising from the dissimilarity of the Ionic capital on its face and flank the Ancients had formed diagonal volutes on the columns at the angles of their buildings; but soon after the revival of Roman Architecture, the want of symmetry which was evident in those capitals was remedied by forming two volutes on each of the four faces in planes concave towards the exterior, and cutting each face of the abacus in the form of a rentrant arc of a circle so as to leave a projection above the two diagonal volutes which meet at each angle; this construction was applied not only to the capitals of the extreme columns, but to all those in a portico or peristyle. Such capitals having a festoon, sculptured to represent foliage, suspended between the catheti of the two volutes on each face, are employed in the Church of St. Peter, and in the Vatican Palace; and are supposed to have been an improvement by Michael Angelo on the volutes of the Temple of Concord. Another form of the Ionic capital was also said to have been invented by the last-mentioned artist; its volute had the appearance of a conical or bell-formed shell, the side of which was turned inward in spiral curves; but this seems never to have been esteemed.

The proportions of the Corinthian column given by Vignola, are nearly the same as those of the columns of Jupiter Stator; the sculpture of his capital is very elegant, except that the tops of the leaves in the second row project rather too much; the same thing may be said of the corona in the entablature, for the lacunaria in the soffit, between the modillons, have the form of parallelograms instead of squares, which is that usually given to them.

Vignola has given two designs for the Composite Order, which chiefly differ in the entablature; one of them resembles that in the Roman edifices; and is ornamented with mouldings of a sufficient boldness to be distinctly seen at a considerable height above the eye. In the other design, the height of the entablature is little more than one-sixth of the height of the column; the architrave is divided into two faciæ without a moulding to separate them, and is crowned by a large ovolo; the frize is ornamented with sculpture, and on each face, at the angle of the building, is a corbel seeming to support the cornice above; over each corbel is a projection like a modillon in the form of a scroll, and supporting a moulding under the corona.

The ornamental doorways of Vignola form a good medium between the ancient and modern style. The aperture is rectangular, and has its height equal to about twice its breadth; the surrounding architrave is divided into three faciæ, which are broken, above, by the horizontal part projecting to the right and left beyond the vertical sides. Above the architrave is a plain frize, and a cornice supported by elegant consoles, the breadth of which at top is greater than at bottom, and they descend to the level of the top of the aperture. In the cornice are both dentels and modillons.

The details above given will convey some idea of the advanced state of Architecture in Italy in the latter part of the XVth and beginning of the XVIth century; and we shall perceive from them that many of the features of Palladio's style had been anticipated by the artists whose names we have already mentioned.

CHAPTER III.

Italian Architecture modified by Palladio.

Palladio improves the style of Italian houses.

Palladio was born in 1518, and therefore must have been for several years contemporary with Peruzzi, San Michaele, and Vignola; and as he lived to the age of sixty-two, he must have practised during a considerable part of the XVIth century. For the number of works he executed, either wholly or in part, and the still greater number of designs he gave, he is to be considered as having done more than almost any other Architect for the advancement of his profession and the embellishment of his Country. It happened, however, with Palladio, as it has happened with some fortunate professor in every other Art and every Science, that much had been previously done by the labours of his predecessors to prepare the way for him, and when he entered the profession there was only wanting a comprehensive mind to combine the materials already existing, into one system. This is what Palladio did; but mankind, in bestowing the meed of praise which was really merited by the author of so many excellent productions, has nearly overlooked what was due to those who had furnished the means by which that excellence was attained. The basis of the practice of Palladio is to be found in the works of the artists of his Country, who lived during the XIVth and XVth centuries; but, instead of imitating the gloomy Palaces of the ancient Nobles of Italy, he introduced a light Architecture, more congenial with the state of society in his time, and capable of being applied, with small modifications, to every other climate The admiration excited by this new style almost immediately caused the heavy mode of building at that time practised, as well without as within the limits of Italy, to be abandoned for that which, in spite of its faults, and they are many, possessed numerous graces. In fact, within a short time from Palladio's death, the Architecture of Italy was adopted in every Country of Europe.

We proceed, in the first place, to give a few specimens of the works of this master; we shall afterward endeavour to exhibit their general characteristics and make a few observations on his style.

The Church of the Redeemer at Venice.

The Church of the Redeemer, built by Palladio, at Venice, is considered by Bertotti Scamozzi as a model of regular and elegant Architecture, though rather beautiful than magnificent. The interior has some resemblance to a Latin cross, but on each side of the nave are three Chapels together, occupying its whole length, which make the breadth of this part of the Church equal to the length of the transept. The length of the interior of the nave is double its breadth; the extremities of the transept and the head of the cross are semicircular, and the centre of the cross is covered by a dome; this is supported by four arches, surmounted by a cylindrical wall, the upper part of which serves as a base for the dome: the choir is situated within the head of the cross and is surrounded by isolated columns. Along each side of the nave, are half-columns coupled and attached to the piers between the Chapels; these Chapels are open towards the interior of the Church; and the apertures are crowned by semicircular arches, springing from entablatures on the capitals of Corinthian pilasters, which are of smaller dimensions than the columns of the nave; between the columns in each pair is a niche and statue. The heights of the apertures are a little more than twice their breadth; and above the entablature of the grand columns in the wall of the nave on each side is a row of three semicircular windows, each divided into three parts by two vertical bars.

The façade is elevated upon a stereobata, to the top of which is an ascent by steps extending all the breadth of the central division of the nave. On this, stands a portico consisting of two three-quarter columns and two pilasters, all of the Composite Order, with a pediment above them. The two wings of the façade are ornamented with Corinthian pilasters; this Order is continued along the sides, and its height is little more than two-thirds of that of the Order in the portico. The doorway has a semicircular head, and is decorated with two half-columns, of the same Order and dimensions as the pilasters of the aisles; and the columns support an entablature with a pediment under that of the portico. The roofs of the aisles are formed in an inclined plane on each side of the Church, and present on the façade the appearance of a great pediment cut in two by the Order of the portico. The height of the Church is 248 feet, its width 94 feet, and the height from the pavement to the top of the vault of the nave is 69½ feet. The base of the dome is elevated upon a cylindrical wall 23 feet high above the ceiling of the nave, and the crown of the dome, exclusive of the lantern, is 27 feet higher.

Bertotti Scamozzi observes that the solidity of this building is ensured by the thickness of its walls, and the resistance against the thrust of the dome is derived from counterforts which rest upon the walls separating the Chapels from each other. The half-pediments and plain, conical pinnacles detract, however, considerably from its merit as a piece of Architecture, though the interior disposition and embellishment may claim our admiration.

Church at Masera.

The Church at Masera, another of Palladio's Ecclesiastical buildings, is circular on the plan, and on one side of it is a recess covered by an elliptical vault; an entablature, supported by fluted Corinthian columns, surrounds the edifice, and between the columns are niches crowned by pediments. In the portico are six Corinthian columns, between the capitals of which are festoons of stone-work hanging in the air; a caprice similar to that which has been executed in some of the Temples of India: the entablature of the columns is crowned by a pediment. The Church of San Francesco della Vigna, at Venice, is considered also as one of Palladio's most esteemed works.

Count d
Porti's
house at
Vicenza.

One of the best specimens of Palladio's town-houses is that which he designed for Count Giuseppe di Porti, at Vicenza, the plan of which is a rectangular parallelogram, 250 feet long and 111 feet wide, the extremities of which fall in two public streets. It consists of two equal buildings separated from each other by a *cortile* or peristyle; an imitation, as Palladio himself asserts, of the Greek houses: only one of these buildings, however, has been executed, and that differs in some respects from the design he has given. In the façade are three stories, of which the lowest is rusticated and contains a semicircular-headed doorway and six windows; on the exterior of the middle or principal story are eight half-columns of the Ionic Order projecting from the wall, with an entablature broken over each; and between the columns are windows terminating in triangular and segmental pediments alternately; the attic or upper story contains eight square windows, and between them are short pilasters, before which statues are placed. Within the entrance is a square vestibule ornamented with four Doric columns without bases; these support an entablature, above which is a groined vaulting covering the vestibule. A vaulted passage leads from this to the cortile, which is surrounded by twenty columns of the Composite Order at the distance of 11 feet 6 inches from the walls; these columns are 41 feet high and nealy 4 feet in diameter; behind them are *parastatæ* or pilasters of smaller height serving to support an open gallery surrounding the *cortile*, by which the communication between the middle stories of the two buildings is made. See pl. xxii.

Rotunda at
Vicenza.

The most elegant of the villas built by Palladio is that called the Rotunda, situated on the gentle slope of a hill near Vicenza. Its general plan is a square, and, according to B. Scamozzi, this figure was given to it that the inhabitants might command the beautiful prospects afforded by the surrounding Country; each side of the square is 69 feet 4 inches long, and on the middle of each face is a portico of six Ionic columns supporting a pediment. In the centre of the square is a circular saloon 34 feet diameter; at the four angles of the square are the four principal apartments, which are of a rectangular form with vaulted ceilings, and between them are small rooms with doors of communication opening into the vestibules between the porticos and the saloon; the staircases are placed at four points on the exterior of the circumference of the latter. The building stands on a basement 10 feet 3 inches high, and containing the kitchens, the dining and servants' rooms; and the walls of the saloon are carried up vertically to the height of 32 feet, above which they terminate in a hemispherical dome. At the height of 22 feet 9 inches from the pavement is a gallery surrounding the interior of the apartment and protected by a balustrade. The bed-chambers surround the upper part of the saloon.

The edifice is encircled at the level of the entablature of the portico by a frize, the exterior surface of which has a small convexity; this kind of frize is always, and sometimes with justice, condemned, but in a building which, like the present, has little exterior enrichment, its effect is not displeasing; the same thing cannot be said of the tablets over the central intercolumniations of the porticos, which were, probably, intended for inscriptions, and of two elliptical windows formed in the tympanum of each pediment. It is probable, however, that these last have been executed since the time of Palladio.

The Vi
Pojana.

As another specimen of Palladio's villas we have chosen that which he designed for Count Boniface Pojana, in a village of the same name, at twenty miles from Vicenza.

The principal story of this building is elevated 5 feet from the level of the ground; it consists of a portico, a vestibule, six chambers, two closets or cabinets, and two staircases leading to the bed-rooms above. In the ground-floor under the principal story are the kitchens and cellars, both of which have vaulted roofs. The façade is broken vertically into five parts disposed symmetrically, two on each side of that in the centre, (which is crowned by a pediment;) and receding from it the portico consists of four rectangular piers supporting two concentric semicircular arches, all in the same plane as the central division of the façade. The want of the horizontal cornice to the pediment is a great defect, but B. Scamozzi supposes it was left out, because the arch of the portico would have approached it too nearly. In the design, a corridor, the roof of which is supported in front by Doric columns, proceeds from the wings of the building to the right and left, and returns on each side at right angles towards the front, so as to enclose an area before the house. See pl. xxii. The two extreme wings of this building have never been executed.

Of the public buildings designed by Palladio for Civil purposes, the Basilica and the Olympic Theatre, both at Vicenza, are the most important, and a description of them may be properly introduced in this place. The Basilica, or Palace of Justice, is supposed by Vincent Scamozzi to have been originally constructed during the reign of Theodoric, King of the Goths; be this as it may, it had become so ruinous by the effect of time and several conflagrations, that Palladio was employed to restore it. According to his own account, in the XXth Chapter of the IIId Book of his Architecture, the porticos or arcades were designed by him, and he considers the building as one of the finest works that had been executed since the time of the Romans.

The plan of the building is a rectangular parallelogram, 170 feet long and 67 feet wide within the walls; the whole consists of two stories surmounted by a high roof of timber, which is covered with plates of copper, and the profile of which is similar in form to a Gothic arch. The lower story, in the interior, is divided longitudinally into three aisles, of equal breadth, by twelve square piers which support its groined vaulting.

Round the exterior of the body of the building are two tiers of arcades, forming corridors 18 feet wide and open towards the exterior; the ceiling of the lower is 25 feet 9 inches from the pavement; that of the upper is 27 feet 6 inches above the former; and the walls of the building are still 17 feet 3 inches higher; therefore, the whole height of the walls is about 70 feet 6 inches from the pavement, and this is independent of the vaulted roof, which is 34 feet higher. On one side of the Basilica the ground is many feet lower than on the other, and here the building is supported by a basement, which adds much by its solidity to the effect of the arcades above.

The exterior of the lower arcade is ornamented with half-columns of the Doric Order attached to the piers, and supporting an entablature which is broken over each column; the intervals of these columns are occupied by four others of smaller dimensions, also of the Doric Order, and placed in pairs perpendicularly to the face of the building; those faces of the piers which are opposite the smaller columns are ornamented with pilasters which, with the columns, support an entablature; this is discontinued at the interval between every pair of columns, and its place is occupied by a semicircular arch, to which the entablature serves as an impost; and the extrados of each arch rises to the inferior surface of the entablature of the principal columns. The upper arcade is exactly similar to the lower, but the columns are of the Ionic Order, and are supported on pedestals; the small columns of both arcades are without bases and have circular plinths. The windows in the upper part of the body of the building are crowned by pointed arches, and these belonged to the original edifice. Above the second arcade, and also on the top of the walls of the Basilica, are elegant balustrades and statues.

The Olympic Theatre.

In the very year of his death Palladio gave the design and laid the foundations of the Olympic Theatre at Vicenza, which was afterwards finished by his son. The rows of seats are of a semielliptical form; their whole extent parallel to the proscenium is 109 feet 4 inches; the horizontal depth from the proscenium to the back of the seats is 42 feet 4 inches; and the proscenium is 80 feet long and 21 feet 4 inches deep. Along the circumference of the upper seat is an elegant row of Corinthian columns 12 feet 6 inches high, above the entablature of which is a balustrade with statues. The façade of the scena, which was designed by Vincent Scamozzi, is composed of two tiers of columns of the Corinthian Order mounted on pedestals; the lower columns are detached from the wall and have pilasters behind them, and the upper Order is composed of half-columns attached. Between the columns, are elegant niches with rectilinear and circular pediments, supported by fluted Corinthian pilasters, and above the upper Order is an Attic ornamented with broad pilasters, between which are sculptures representing the labours of Hercules. In the scena, are three large open doorways leading through five passages, three of which diverge from the central doorway to the interior of the scena. The sides of these passages are ornamented with perspective representations in relief of Temples, Palaces, Basilicas, &c., executed in wood, and producing a surprising effect. The whole of the internal distribution seems to have been made according to the practice of the Romans, as nearly as the limits of the ground would permit.

Design for a bridge.

Palladio has given several designs for bridges, among which is a very elegant one, supposed by Temanza to have been intended for the Rialto, at Venice: if this is the case, the design of Palladio was not adopted, and, instead of it, was chosen one given by Antonio da Ponta. On the bridge are indicated one grand central street and two lateral ones, and on each side of all three, a row of shops; the whole construction is supported by three semicircular arches resting on rusticated piers. The ascent to the roadway is by three flights of steps at each extremity of the bridge, one parallel to its length and two at right angles to it; consequently, the bridge could only have been intended for foot-passengers, and, probably, to serve as a sort of Exchange for the meetings of the merchants. At each extremity, and over the central arch of the bridge, is a portico, consisting of Corinthian columns with square pilasters at the angles, and having above it a pediment-roof.

Characteristics of Palladio's style.

Like his contemporaries and immediate predecessors, Palladio was chiefly employed in designing and erecting houses for the Italian Nobility, and his designs for that kind of building are those which have been of the most importance in forming the taste of succeeding Architects. His ground-stories are generally composed of arcades serving as basements for the upper stories which are ornamented with columns, and in these basements were the offices or apartments used as shops; the principal story, or, as it is called, the *piano nobile*, is above these, and the Attics were reserved for store-rooms. He gave small extent to his façades, in order that the length might be nearly equal to the height; and, frequently, in the midst of the façade he made an anterior vestibule with three arches or rectangular apertures in front.

In the distribution of the interior of his buildings, he conformed to the taste and customs of his Age. It is said that at that time the Nobles required vestibules and peristyles, and apartments of great capacity to serve as Libraries and Galleries of Painting and Sculpture; and in these respects, Palladio's dispositions are considered as excelling those of his contemporaries. His arcades consist either of simple semicircular arches resting on piers, or the interval between two principal piers is divided into three parts by small piers or columns, and the arch covers only the central aperture; a construction which seems to have been copied from some of the colonnades of Dioclesian's Palace. Palladio's windows, though generally terminating above in a horizontal lintel or simple semicircular-headed arch, are sometimes divided into three parts, and have the central division arched in the manner we have just described; and often the windows are only semicircular apertures divided into three parts by two vertical bars or mullions, as in the Churches of the Redeemer and of San Georgio Maggiore, at Venice.

A marked distinction between the mansions designed by Palladio and those of the preceding Age appears in the almost constant application of a pediment to the central part of the principal façade; this is supported on the attached columns of the *piano nobile* and imparts an air of majesty to the whole edifice. The height of the pediment is made to vary from one-fourth to one-sixth of the length of the horizontal cornice, and to depend inversely upon the number of columns below it; a judicious modification, which renders the height of the pediment nearly proportional to that of the building itself. A great departure from the principles of the Art is, however, found in a few of the pediments which crown the façades of Palladio's buildings; we allude to the want of the horizontal cornice that should connect the lower extremities of the inclining rafters; an example of this bad taste occurs in the Villa Pojana which we have above described.

In the Churches which Palladio has erected he seems to have made an effort to preserve the general form of the Basilican or Lombard Churches, and to adapt the Roman Orders to it instead of returning to the form of a Heathen Temple, to which the buildings for Christian worship certainly have no relation. In the Lombard Churches the nave has considerable elevation, and the side aisles are subordinate to it; this form he retains, but he changes the façade with its tiers of arches for a portico consisting of columns mounted on pedestals and supporting an entablature with a pediment above, the apex of which reaches to the roof of the nave. On the two sides of the portico are the extremities of the aisles with those of their inclining roofs; the latter may be supposed to be parts of a pediment-roof once common to the whole building, and cut by the side walls of the central division of the nave: such is the construction of the Churches of the Redeemer, of San Georgio, and of San Francesco alle Vigne, all at Venice. The façade indicates by this form the disposition of the body of the Church; and though a better Taste may condemn the appearance of a double pediment, there is, at least, a reason for employing it.

In dividing the interior of houses, Palladio proposes several different proportions between the length, breadth, and height of apartments. Where circumstances admit it, which he acknowledges to be rarely, he recommends the rooms to be circular; in other cases, he recommends them to have their breadth equal to their length, or in a ratio to it which varies from that of 1 to $1\frac{1}{3}$ to that of 1 to 2, and that their heights should be an arithmetical mean between the length and breadth; in some of his best buildings he has made the ratio of the breadths of the principal apartments to their lengths as 1 to $1\frac{2}{3}$, and the heights equal to the arithmetical mean; the small rooms are square and the length or breadth to the height in the ratio of 1 to $1\frac{1}{3}$. The proportions of doorways are by the Italian artist made nearly the same as those prescribed by Vitruvius for the Doric Order, but the antepagments do not diminish. He makes the height of the windows in the ground story equal to $2\frac{1}{11}$ of their breadth, and the height of those in the second story equal to $2\frac{1}{8}$ of their breadth; consequently, these appear talle than the windows below them; a practice which Palladio seems to have generally adhered to, though in his *Architecture* he recommends them to be shorter by one-sixth.

Modification of the Orders by Palladio.

The modification which Palladio has made in the Tuscan Order does not differ much from that made by Vignola; both have made the heights of the column and of its base and capital to bear the same proportions to the diameter, but Palladio has made the diminution of the shafts greater, the difference of the diameters being one-fourth of the lower diameter. Palladio's capital has the advantage of greater simplicity than that of Vignola, the abacus being without any moulding, and the projection of the ovolo being only equal to about half its height; on the other hand, Palladio's entablature is higher and more complex, its height is equal to one-quarter of that of the column, and the mouldings of the cornice seem too numerous for an Order which should possess the utmost simplicity.

In many of the edifices of Palladio's time we find the shafts of the Tuscan columns occupied at intervals by cylindrical or cubical blocks, as we have already said; this rustication, though hardly to be recommended in any case, is not inappropriate to a building characterised by a certain degree of rudeness, and examples of it are to be found in some of the old Roman works: in one of the aqueducts, the columns, though of the Corinthian Order, have their shafts broken by those heavy masses.

In the Doric Order, also, Palladio has deviated but little from Vignola; the heights and forms of the column and of its base and capital are the same, but the diminution is less, for the difference of the upper and lower diameters is $\frac{1}{7.5}$ of the latter; the architrave is divided into two faciæ, the centres of the triglyphs correspond with the axes of the columns, the metopes are square and ornamented with sculpture; the soffit of the corona is in an inclined plane, and this member has neither the dentels nor mutules which Vignola has given to the Order; in this respect, therefore, Palladio's Order has gained something on the score of simplicity: the height of the whole entablature is $\frac{1}{4.5}$ of the height of the column.

Palladio's practice varied considerably respecting the proportions of the Ionic Order, but one which he has employed more frequently than the rest, and which he has given in his *Architecture*, resembles that of Vignola only in the proportion of the height of the column to its diameter, in the height of the base and capital, and in the form of the latter. Palladio has employed the Attic base with an astragal above the upper torus, and he has given rather less diminution to the shaft, for the difference of the upper and lower diameters is but one-eighth of the latter; the architrave is divided into three faciæ separated from each other by mouldings; the frize is deformed by making its surface convex, which, though justified by many examples of antiquity, is hardly worthy of imitation; and under the corona is a row of plain modillons; the height of the whole entablature is but one-fifth of that of the column, which seems too little and gives an air of meanness to the Order.

Palladio's design for an Ionic capital, like those of the Ancients, and of Alberti, Serlio, and Vignola, represents the planes of the faces of the volutes to be parallel to the face of the entablature, the sides of the capital having the usual baluster form; the volutes, however, of the Italian Architects are invariably smaller than those of the Ancients, and on that account are far from possessing the elegance which characterises the latter.

Subsequently to the time of Palladio, Scamozzi designed an Ionic capital which seems a variation of one of those given by M. Angelo; the planes of his volutes are parallel to the diagonal of the abacus, and the faces of the latter are concave towards the exterior; the stems of the volutes spring from the middle of the capital, and between the lower extremities of the stems is a flower on each face which fills up the void under the middle of the face of the abacus. In this capital the ovolo seems to represent a circular vase placed on the top of the column, and the volutes to represent the curling heads of plants rising from its interior.

The height of Palladio's Corinthian column is but equal to 9.5 diameters, whereas Vignola had made it equal to 10 diameters, which is more agreeable to the practice of the Ancients; the base resembles the Attic, but it has, in addition to the other members, an astragal above and below the scotia and above the upper torus; which is not, perhaps, improper in the Corinthian Order, though it produces a departure from that alternation of rectilinear and curvilinear features which constitutes distinctness and relief. The diminution of the shaft is rather less than Vignola makes it, and the heights of the several members of the entablature bear a lower ratio to the diameter; the architrave is divided into three faciæ, and the frize is connected with the upper moulding of the architrave by a conge or inverted cavetto. The height of the whole entablature is equal to $\frac{1}{52}$ of the height of the column, and the cornice contains both dentels and modillons.

Palladio makes the Composite column equal to 10 diameters in height, like that of Vignola, but the diminution less: the architrave is divided into two faciæ, and the frize resembles that in the Ionic entablature, except that the upper part of the swollen or convex surface projects beyond the lower as much as $\frac{1}{15}$ of a diameter; this practice, which at first seems extraordinary, has probably been adopted, as is observed by Norman in his parallel of the Orders, to reduce the intervals of the modillons in the cornice to the form of exact squares when the centre of a modillon corresponds to the axis of each column. The height of the entablature is one-fifth of that of the column, the cornice is without dentels, and under the corona are modillons which are divided horizontally into two parts by a moulding; the lower part is smaller than the upper.

CHAPTER IV.

Architecture of the Continent of Europe since Palladio's Time.

Decline of Architecture in Italy.

Two Architects who have added lustre to their profession both by their buildings and writings, *viz.* Serlio and Scamozzi, were contemporaries with Palladio, and both practised in the North of Italy during the XVIth century; Scamozzi is particularly celebrated for the Trissino Palace, at Vicenza, the façade of which exhibits two stories, the lower ornamented with Ionic columns, and the upper with Corinthian pilasters. To these names we may add those of Scalfarotto and Tirali, the former of whom built the Church of San Simeone Minor, at Venice, with a façade in imitation of the front of a Roman Temple, consisting of six Corinthian columns supporting an entablature, and crowned by a pediment enriched with sculpture; and the latter subsequently added a portico of a similar kind to the Church of San Nicolo in the same city. These are almost the first of the Italian Churches having that kind of portico; the façades of the others being generally ornamented with three-quarter columns attached to the walls.

But from the end of the XVIth to the beginning of the XVIIIth century, the Architecture of Italy is found to have deviated considerably from the comparative purity of the Palladian School; columns of the Roman Orders were grouped together like those in a Gothic edifice, and they were employed to support the imposts of arches by the side of others which bear an entablature passing above the crowns of the same arches; pilasters were made to project before each other, and the entablatures were broken to correspond with the projections; and lastly, pediments were placed one within another, or were interrupted at the vertex; and an excess of misapplied ornament encumbered every part of the building. It must be admitted that examples of these improprieties are found in the works of the older Architects; but in these they appear but as accidental defects, whereas in the Age we are speaking of they became general.

Borromini.

During this period lived Borromini, against whom is chiefly directed the reproach of corrupting the style of the Italian Architects. This artist practised during the first half of the XVIIth century, and made himself singular by the extravagant caprices which he introduced. The best of his works is the Church of Santa Agnesi in the Piazza Navona, at Rome, the façade of which is a curve of contrary flexure on the plan, and is ornamented with Corinthian columns. Another of his works is the Church della Sapienza, also at Rome, the plan of which, in the interior, is a triangle with a semicircular recess on each side, and having its angles filled up. The lower part of the Church is invisible from without, being surrounded by buildings, but, above, is a cupola, the exterior surface of which is formed in steps surrounding it, except where they are interrupted by counterforts; but the most remarkable object in this building is a spiral turret, approaching to the form of a cone, which crowns the dome.

Palazzo Barberini.

About the same time lived Bernini, who, besides the colonnade in front of St. Peter's Cathedral, built the façade of the Barberini Palace, at Rome. The centre of this building, which had been designed by Carlo Maderno, and partly executed by Borromini, is of a rectangular form, and there are two wings which project towards the front; on the ground-floor of the centre are two parallel rows of arches on piers, forming a vestibule which is covered by a groined vaulting; and in the elevation of the front are three stories, of which the lowest is ornamented with Doric columns and the two upper with columns of the Corinthian Order; and between the columns are semicircular arches springing from imposts. In the front of each of the two wings, are three tiers of rectangular windows, placed in recesses formed by four narrow projections of the wall like pilasters; and above the roof of the central division is a rectangular building called a *Belvidere*, with windows on each side and adorned with pilasters on the exterior. This kind of turret seems to have been affected by the Nobles of Italy at that period, and there is one of a magnificent character above the roof of the Pontifical Palace erected by Fontana; but they are considered by Forsyth as injuring the effect of a building, and as resembling a hut on a house-top.

The Caserta, at Naples.

We may here introduce a description of the Palace of the King of Naples, at Caserta, designed by Van Vitelli, in 1752. This splendid edifice, which from its immense extent produces a sublime effect, consists of four ranges of buildings disposed on the sides of a rectangle 710 feet long, and 610 feet broad, with a square pavilion at each angle rising above the general roof; and the interior is divided into four equal-sized open courts by two lines of buildings which cross each other at right angles in the centre. The entrances are by an octagonal vestibule in the middle of each of two opposite faces; and a grand but obscure corridor extending quite through the building connects these vestibules together. In the middle of this corridor, and in the centre of the whole Palace, is a grand, octagonal saloon, on one side of which is an immense marble staircase, leading to an octagonal landing-place over the saloon. On that side of the landing which is opposite the head of the stairs, is a superb chapel, of a rectangular form, but with a semicircular recess at one end: its ceiling is hemicylindrical, divided into compartments richly gilt, and rises on each side from an entablature supported by coupled Corinthian columns of marble, which stand on pedestals united by balustrades. In the middle of one of the sides of the enclosure is an elegant Theatre.

The exterior façades of the building are 120 feet high from the ground; each consists of three stories, of which the lowest is rusticated, and contains two rows of rectangular windows with three plain entrances covered by semicircular arches. Above this basement is a row of Ionic pilasters standing on pedestals, the faces of which project from a general podium, and above the entablature is a balustrade with statues; between the pilasters are two tiers of rectangular windows, of which the lower only are terminated by pediment-heads; and the centre of the façade is marked by a grand pediment supported by four pilasters and crowned by trophies. The upper part of the pavilion, at each angle of the Palace, is adorned with Corinthian pilasters, and over the centre of each face of the pavilion is a pediment. The whole building stands on a general basement, to which is an ascent by steps extending quite along the front.

Since the commencement of the XIXth century the taste for the classical Architecture of the Romans has more generally prevailed in Italy, and specimens are exhibited in some of the Churches at present in progress; of these the principal are the great Church at Naples, now building by an artist of the Country, and a Church in Lombardy, building according to the design and at the expense of the late celebrated sculptor Canova: the former is crowned by a dome of pumice-stone; and, in the interior, is one great Order rising up to near the foot of the dome, with continuous bas-reliefs above the entablature; on the exterior is a Corinthian portico with a pediment and a Doric colonnade in front like that at St. Peter's Church: the other is executing on the model of the Pantheon, and is to have a Greek-Doric portico in front.

Architecture of France in the XVIth century.

Before we describe the Architecture of the Northern part of the Continent of Europe in the XVIIth and XVIIIth centuries, it will be necessary for a moment, to cast a look back on that which prevailed in France immediately after the abandonment of the Gothic style. The dwellings of the Nobility of France about the time of Francis I. were generally in the castellated style, and though not intended as fortresses, they probably resembled such as were actually places of defence in the turbulent times which preceded that period. The plan was a square or parallelogram, and the whole consisted of buildings surrounding an open court; the windows were high and narrow, and at each angle was a square or round tower, crowned by an embattled parapet, with machicolations, and terminating in a high pyramidal or conical roof. Most of the buildings stood on a terrace, supported by a sloping wall or revetment, and at each angle of which was a *guérite* or watch-tower projecting beyond the wall. Specimens of such edifices, probably in their original state, still exist at Montargis and Verneuil. See Durand's *Parallel of Ancient and Modern Architecture.*

In the beginning of the following century, and probably earlier, a taste for extravagant ornament prevailed on the dwelling-houses both of France and Germany. The old houses yet existing in Normandy, Germany, and Holland have octagonal towers, high roofs, and disproportioned columns with spiral flutings; and the faces of the walls and the *dormers*, or windows in the roofs, are covered with the utmost profusion of sculpture. Some examples of these buildings may be seen in Cotman's *Antiquities of Normandy;* but in the course of that century the Architects, having adopted the style of the Italian School, introduced a taste for greater simplicity and elegance.

The Luxe
bourg.

One of the first examples of this improved style is the Chateau Luxembourg, built by De Brosse, under Mary de Medicis, in 1620; this consists of a centre and two wings connected by arcades; each of the wings is formed by two square pavilions placed at right angles to the front, and in the rear is a square court surrounded by a double arcade. The central building is crowned by a cupola and lantern, and the pavilions by roofs in the form of frusta of pyramids; each consists of three stories ornamented with columns, and coupled half-columns are attached to the faces of the piers supporting the arches which connect the buildings. The chief defect in the design of this building is that the pavilions instead of being subordinate to the centre are both broader and more lofty, and the high, plain roofs seem too heavy for the ornamented walls which support them.

The Louvre and the Thuilleries are two buildings separated only by their gardens; the former consists of a vast quadrangle enclosing a *cortile;* and the magnificence of its principal front, which was built by Perrault, in 1667, renders it one of the finest buildings in Europe; the length of this front is 371 feet, its height from the level of the ground to the top of the cornice is 85 feet 3 inches, and it is broken vertically so as to form a projection in the centre and one at each extremity. The basement constitutes one grand but plain podium, 32 feet 3 inches high, and is pierced by windows, the upper extremities of which are flat segments of circles; in the central division are three doorways, of which that in the middle is more lofty than the others, and covered by a semicircular arch crowned with trophies. Above the podium, the central division and the two curtains connecting it with the pavilions are adorned with coupled, Corinthian columns having fluted shafts; every pair stands on a pedestal common to both, and between the pedestals are balustrades: the columns stand at a distance from the walls, and behind them is an open gallery extending along the front. In the middle of the face of each pavilion is a recess crowned by a semicircular arch springing from imposts; the angles of the pavilions are ornamented with coupled, Corinthian pilasters, and on each side of the recess is a column and pilaster. In the wall of the building, under the colonnade, are niches containing statues, and each niche is crowned by a pediment; above these is a horizontal string, and over it a row of elliptical medallions. The central division is crowned by a magnificent pediment, the tympanum of which is filled with sculpture, and above the horizontal cornice of the rest of the building is an elegant balustrade.

The Thuilleries form one line of building, 1070 feet long, situated at that extremity of the whole which is opposite to the colonnade front of the Louvre. The centre consists of a tower, 74 feet square, crowned by a high dome raised on a square base, and formed of four curved surfaces meeting in as many diagonal ridges, which are ornamented or disfigured by rusticated work; on each side of the centre, a line of building, having an arcade in front, connects that part with each wing.

The façade, which was designed and begun by Philibert del' Orme in the middle of the XVIth century, and continued by Le Vau in the XVIIth, presents the appearance of a mass of discordant parts; that in the centre consists of four stories, ornamented with Ionic and Corinthian columns supporting entablatures, and crowned by a pediment and dome. The arcades in the curtains stand on a podium broken by projections; the faces of their piers are ornamented with Ionic columns, the shafts of which are interrupted by cubical blocks, and above the arcades are two tiers of windows. The façade of each of the wings is broken vertically into three parts, of which that nearest to the centre consists of three stories, with Ionic and Corinthian columns in the lower and second stories respectively, and Attic pilasters in the upper. The parts at the extremities of the façade consist each, also, of three stories; the front is adorned with four Corinthian pilasters extending from the podium to the top of the second story; and over these, are dwarfish pilasters of the same Order, in front of the third story; these extreme buildings are covered with lofty roofs, in the form of frusta of pyramids. The curtain between the two extremities of each wing consists of two stories only, in front of which are coupled, Corinthian pilasters, supporting an entablature above the second story.

In the façade of this Palace there is a mixture of columns and pilasters of various Orders and sizes ranged in the same line; two and three stories are formed within the same height, with entablatures terminating at the point at which the heights of the stories are changed, and the roofs of the several buildings are separated from each other; hence arises the utmost confusion in the system, yet from the great extent of the line an imposing effect is produced.

Palace of Versailles. A still more imposing effect arises from the immense line of buildings forming the Palace at Versailles, which, besides the advantage of greater regularity of design, is without the high naked roofs which deform the older buildings of France and appear like mean additions to the original structure. This edifice was built by Hardouin Mansard in the time of Louis XIV., and consists of a series of buildings divided into two parts by a court; the whole length is 1330 feet, and from the centre projects a mass of buildings about 250 feet towards the garden. On arriving from Paris there is a front court, in advance of the general line of building, with offices on each side, and this leads to an inner court between the two wings; at the bottom of this is the grand portico in the centre of the whole building. The two wings and the centre contain five quadrangular *cortili* surrounded by the apartments of the Palace, and the two extremities of one wing are occupied by a Chapel and a Theatre.

The Escurial. The royal Palace of the Escurial, in Spain, was begun in 1557 for Philip II., by Giovan Battista di Toledo, and finished by other hands after the death of that Architect. It is of a quadrangular form, 680 feet long from North to South, and 558 feet from East to West, besides a Chapel which projects 177 feet beyond the face of the Eastern front; the general height of the edifice is 64 feet, but there are eight towers, each 200 feet high, of which four are at the angles and the rest are symmetrically disposed in the interior. The general plan of the building may be considered as divided into three parts, in directions from West to East; at the Western extremity of the central division is a grand vestibule 252 feet long, and 125 feet wide, the sides of which are ornamented with pilasters supporting arches. Three grand portals lead from this vestibule to the Royal court, which is 262 feet long, and 197 feet wide, including the habitations about it; the façades of the buildings in this court have five rows of windows, ornamented with pilasters or fasces; and at the Eastern extremity is the grand Chapel, which is covered by a cupola 70 feet in diameter, and has in front a portico formed by five arches, the piers of which are ornamented with half-columns of the Doric Order. The Northern and Southern divisions of the interior are occupied by peristyles or arcades surrounded by apartments.

The principal exterior façade is towards the West; like all the others it contains five tiers of windows, ornamented with simple architraves; and it is finished by a horizontal cornice which is continued without interruption round the whole building. It has three portals of entrance, one in the centre and the others equally distant from it and from the angles of the building. The centre of the façade is adorned with two Orders of half columns attached to the walls; the breadth of the lower Order is 149 feet; and it contains eight Doric half-columns standing on plinths; in the middle intercolumniation is the doorway, and in the others are niches. Above the entablature of this Order are four Ionic columns, placed vertically over the four middle columns of the Order below; and the entablature is crowned by a pediment with a globe at each of its points; this second Order is flanked by four obelisks placed vertically over the four extreme columns below; the obelisks are terminated by globes; and in the middle intercolumniation is a niche containing a statue of San Lorenzo; the decorations about the other doorways consist of architraves and pediments.

The size of this building gives it an air of great magnificence, but its long and almost naked façades render it a gloomy pile.*

The high, sloping roofs, which we have described as rising above the walls of the Palatial buildings in France, seem to have been general throughout the North and West of Europe, during the last century, in the palaces, villas, and even the town houses; but this mode of building was carried to excess in Germany, where the roofs were often as high above the tops of the vertical walls as these were above the ground, and contained sometimes as many as five rows of dormer windows.

We add to this Chapter an account of the two principal, modern Churches of France, which are distinguished from those of Italy chiefly by the manner in which the centres of the buildings are covered; instead of the massive double domes which seem to crush the walls of St. Mary's, at Florence, and of St. Peter's, at Rome, the French Churches are crowned by slender cupolas exhibiting, in their construction, examples of refined, mechanical skill.

Church of the Invalids, at Paris,

At the latter end of the XVIIth century, Hardouin Mansard, the Architect of the Thuilleries, built the Church of the Invalids, at Paris, a work of the same character as that of St. Peter's, at Rome, but of smaller dimensions. This edifice is formed on a plan the exterior of which is a square of 342 feet, and the central part in the interior is a complete circle, 85 feet 3 inches diameter; between this circle and the four faces of the building are vestibules, which give to the interior the form of a Greek cross, and the vestibules on the East and West are terminated by porticos. Within each of the four angles of the square, is an octagonal Chapel; and in the Eastern extremity of the Church is a rich baldaquino, the entablature of which is supported by Corinthian columns with twisted shafts.

The body of the Church is covered by a triple dome, of which the lowest has the form of a spherical zone, and rises at 146 feet from the pavement; its height is 36 feet, and it terminates in a circular aperture which permits the second dome to be seen by a spectator below; this second dome, which is nearly a hemisphere, rises from the hances of the former, and its crown is 208 feet from the pavement. Both these domes are of masonry; the lower part of the second is pierced by twelve semicircular-headed apertures. The third or upper dome is of timber, and its vertical section resembles a Gothic arch of the third point; its vertex is 238 feet from the pavement, and it is crowned by an elegant lantern, terminating in a ball and cross, at 312 feet from the pavement: the surface of the exterior dome is divided by twelve ribs, and between these it is ornamented with panels containing painted trophies; the interior surface of the second dome is covered with painting, on which the light falls from the windows in the lantern, and permits them to be seen to great advantage, through the aperture of the lower dome.

of St. Genevie

The Church of St. Genevieve, at Paris, was begun, in 1757, by M. Soufflot, and is remarkable for the boldness of the construction of its upper part, which consists of three domes of masonry raised one on another without any apparent abutment. At the intersection of the body of the Church with the transept, are four piers, ornamented with Corinthian columns; from these piers spring semicircular arches, and between them are pendentives, which terminate in a horizontal circle 70 feet in diameter, with an interior entablature, the cornice of which is 108 feet from the pavement; above the pendentives is a cylindrical wall, in which is another interior entablature, the cornice of which is 155 feet from the pavement. The exterior of this wall is surrounded by a range of Corinthian columns, 37 feet high, and disposed in the circumference of a circle, 110 feet in diameter; from the top of the wall springs the lower dome, which is 70 feet in diameter, and 35 feet high, and has the form of a truncated paraboloid ending at top in a circular aperture, the diameter of which is 30 feet.

On the hances of this dome, and 180 feet from the pavement, springs another parabolical dome, 58 feet in diameter, and 40 feet high, and on the top of this is a lantern, 55 feet high, with a hemispherical top, terminating in a ball and cross. Over the cylindrical wall before mentioned, and on the exterior of the base of the second dome, is another cylindrical wall, crowned on the exterior by an entablature, the cornice of which is at the height of 200 feet from the pavement; from this springs the upper dome, which is 80 feet in diameter, and 40 feet high, and terminates on the exterior of the lantern, at about the middle of its height. A vertical section of this dome presents the appearance of two Gothic arches, the radii of which are each equal to 54 feet.

General style of Church building the Continent.

After the description of the elegant Churches of Italy and France, it will be almost needless to notice those of other Countries on the Continent of Europe, which have been erected subsequently to the abandonment of the Gothic style; some of these, like the Cathedral at Dresden, are crowned by magnificent domes, but in general they are furnished with a square or polygonal tower rising to a great height above the body of the building; the top of this is surrounded by a balcony and crowned by a cupola and lantern, and frequently by a small spire or pinnacle above the latter. In Holland and the Northern part of Germany, an extremely vitiated taste prevailed till lately in Church building; many of the spires, instead of having the simplicity of the pyramid or cone, resemble several spheroids or bell-shaped figures placed one above another, and ending in a very acute pinnacle at the top.

The modern Churches of Spain are not very different from those of the North of Europe; some of them are crowned by domes, but the generality of them have only small slender turrets extravagantly painted and gilt; their marbles and paintings are rich, but are overloaded with garlands and pyramids, broken pediments, and heavy cornices.

CHAPTER V.

Introduction of the Roman Architecture into England.

The introduction of the revived Roman Architecture into England seems to have taken place during the

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* For particulars of the ESCURIAL less strictly Architectural, see our *Miscellaneous Division, ad v.*

reign of Henry VIII., for this Prince had in his service John of Padua and Jerome of Treviso, two Italian Architects, who were employed in the erection of mansions for the English Nobility; and, though nothing now remains of their works, there is little doubt that they were the instructors of Holbein, who arrived in this Country at or near the same time; and who has left an example of the ancient Orders, but blended with features belonging to the latest species of Gothic Architecture, in the portico which he built for the Earl of Pembroke, at Wilton.

e of ding in time of abeth James I.

s Col-, Cam-ge.

This mixture of styles continued to prevail in the buildings erected during the reigns of Elizabeth and James I., and specimens of it are found in the Colleges at Oxford and Cambridge, several of which were then built or restored; these generally consist of ranges of buildings enclosing quadrangular areas; and the windows, which are rectangular, are divided by mullions and crowned by horizontal tables. Over the gateways are oriels, and along the tops of the walls are several gables, the sides of which are cut in figures fantastically composed of right lines and curves. But in Caius College, at Cambridge, which was erected in 1566, are several semicircular-headed gateways, ornamented with some of the Roman Orders in tiers; and the face of one of them has all the five placed, in succession, above each other. For purity of style these are nearly equal to any examples of the Orders executed by Bramante in Italy.

ools at ord.

The tower also of the Schools, at Oxford, consists of a semicircular-headed gateway with broad windows above it, and the whole crowned by a complex gable; on the face of the tower are five tiers of coupled columns of all the different Roman Orders, from the Tuscan to the Composite, mounted on pedestals. These are supposed to have been executed by Inigo Jones; but they are probably older, and are, evidently, the work of some person who had a knowledge of the Orders, but not of the ancient mode of applying them in a building. Above the second tier of windows is a statue of James I.

abethan sions.

According to Mr. Walpole, the mansions of the Elizabethan Age belong to a style which he supposes to have been invented for the houses of the Nobility, when, on the settlement of the Kingdom after the termination of the quarrel between the Roses, they ventured to abandon their fortified dungeons and consult domestic convenience. At the entrance was a vast hall frequently occupying all the height of the building; from this proceeded a gallery extending through the whole length of the house, and forming a communication among the different apartments. The apartments themselves were great in length and breadth, but the ceilings were low; and those sides of the room which were formed by the exterior walls of the house were almost entirely occupied by rectangular windows: oriels or bowed windows were also very general; these formed recesses in the rooms, and were supported by timbers projecting from the face of the lower part of the wall. The ceilings were divided into square compartments by great timbers under its general surface; the parapets were cut into gables like those of the Colleges above mentioned, and both the interior and exterior of the building were generally loaded with sculptured ornaments resembling those on the houses of the Continent, at the same period.

An Architect named Thorpe designed or improved most of the Palatial edifices erected in the reigns of Elizabeth and James I. Walpole says of him, that his ornaments are barbarous; but he allotted ample spaces for halls, staircases, and chambers of state, and there is judgment in his disposition of apartments and offices. Audley End, near Saffron Walden, and part of Northumberland House in London, were built by Bernard Jansen, a Fleming, in the time of James I. The latter is remarkable for its almost exact coincidence with the style of the Italian Palaces; consisting of a range of buildings surrounding a quadrangular enclosure, with windows towards the interior.

Bernard Jansen.

Brownsholme Hall.

In Britton's *Architectural Antiquities* is given a view of Brownsholme Hall, in Yorkshire, which may serve as an example of the domestic Architecture of the above-mentioned period. The façade consists of a centre and two projecting wings. In the middle of the former, is the doorway which is crowned by a semicircular arch without imposts, and on each side is a pair of fluted columns of an Order resembling the Doric, but with Attic bases, and standing on a common pedestal; the entablature above them extends only over the doorway and columns, and is broken so as to project over the latter; in the frize are triglyphs, but placed without regard to symmetry, for in that part which stands over the capitals of the columns there are two triglyphs, and two metopes, so that at one angle of the projection is a triglyph, and at the other a metope. Over this entablature is a plain rectilinear window, and, on each side of it, a pair of Ionic, fluted pilasters, both standing on one pedestal, the face of which is ornamented with a panel; the entablature above consists of several mouldings, without distinction of architrave or frize. The third story is ornamented in a way similar to the second, but it is not quite so high; over it is a pediment, and, on each side, is a small obelisk, placed on a pedestal.

Improvement of English Architecture by Inigo Jones.

The English mansions of the time of Elizabeth do not appear to have been ever considered as convenient dwellings; Lord Bacon's observations on them are well known, and perhaps there are few persons of the present day who would choose such edifices for their residence in preference to those of more modern construction; the tasteless form of the exterior, the great square windows, and clumsy sculpture, are equally unworthy of imitation; and, we may add, the diminutive columns executed in imitation of the Roman Orders, and placed so that they betray an utter ignorance of the principles which regulate the employment of such members, instead of inspiring ideas of magnificence only excite contempt. But this mixture of styles did not long continue, and the Italian artists, who had been brought into England as early as the reign of Henry VII., having communicated some knowledge of the Architecture of their Country, those of England began to feel a desire to be more intimately acquainted with it, and with the ancient style from which it was derived. By such means Inigo Jones seems to have been led to the study of the writings of Vitruvius and of the Italian Architects; and, thus, to have acquired a great taste for the style prevalent in Italy at that period, which, fortunately, he was enabled to put in practice to a great extent.

St. John's College, Oxford.

In the early part of his professional career, he gave designs for the second quadrangle of St. John's College at Oxford; the lower story of which he made to consist of a range of semicircular arches supporting an entablature ornamented with triglyphs; above this, are windows divided into two lights, and the walls are crowned by battlements. In the centre of one side of the square is a semicircular arch, springing from columns, and on each side of it is a projecting pier with double, fluted pilasters supporting an entablature in which are two triglyphs. In the second story of the same centre, and above the former pilasters, are two similar ones with Ionic capitals; the whole of the centre is crowned by a segmental pediment without the horizontal cornice. About the same time Jones built Heriot's Hospital at Edinburgh, and Sherbourne House in Gloucestershire; these first works, however, have not the correctness observed in those executed after his return from Rome; and Walpole observes that his designs of that time are defaced by the littleness of parts and weight of ornament with which the revival of the ancient Architecture in this Country was, for the most part, encumbered. But, having had an opportunity of consulting on the spot the remains of Roman Art, his taste became purified, and, subsequently, he designed or executed those works which established his fame, and gave a decided turn in England in favour of classical Architecture.

Intended Palace at Whitehall.

King James employed this Architect to give a design for a new Palace at Whitehall, in order to replace the ancient one, which was then in a ruinous condition; and a complete plan and elevation of the intended Palace may be seen in the collection of his designs by Kent: it was to have been of a rectangular form, the whole length, between the river Thames and St. James's Park, equal to 926 feet, and the breadth from North to South 740 feet. This immense edifice, exceeding in magnitude the Palace of Dioclesian, was to be divided into three equal rectangles by two ranges of buildings, extending through the whole depth of the Palace, from North to South; the central division was to form one great court surrounded by a terrace 30 feet wide; but the two lateral divisions were each to be divided into three courts by two ranges of buildings from East to West. In the centre of each of the exterior sides of the building there was to be a grand façade, of which that next to Charing Cross, and the opposite one, were at the extremities of the great central court; the front next to the Park was to lead into a circular, or as it was called, a Persian court, surrounded by an arcade, and forming the middle of the three courts on that side of the Palace; the front next to the river was to lead into a square court, also surrounded by an arcade, and forming the middle court on this side.

Banqueting-house.

The only part of this vast edifice which was executed is that intended to have been a Banqueting-house, but now converted into a Chapel; it forms a very small part of the whole design, and occupies what would have been the Western side of the quadrangle at the North-East angle of the Palace. Its plan is a rectangle 110 feet long, and 55 feet wide, and its longest fronts contain each two Orders of half-columns, above the lowest story, which forms a substantial basement to the whole structure; the lower of the two Orders is Ionic, and resembles that of Palladio in the proportions of the columns, in the convex frize, and in the modillons of the cornice; between the columns are rectangular windows, with circular and rectilinear pediments alternately: the upper Order is Composite; between the columns are rectangular windows, and above the latter are festoons of sculptured drapery: the whole front is rusticated and crowned by a balustrade. The façades of this building produce an imposing effect, and they are so much the more admirable as they are almost the first examples of the Roman Architecture in this Country; they partake, however, of the defects of the Italian school, from which emanated the style they exhibit; the entablature is broken over each column, and there is a cornice to the lower, as well as to the upper Order. But if the whole Palace had been executed, there would have been no ground for the observation of a foreign artist, which till lately was too well founded, *viz.* that the King of England was worse lodged than any other Prince in Europe.

The old Palace at Whitehall, which this was to have replaced, had been originally built by Hubert de Burg, Earl of Kent; it was in 1248 sold to the then Archbishop of York, and it became the town-residence of the Prelates of that See. In 1530, Cardinal Wolsey, who then held it, sold it to Henry VIII., by which it became the property of the Crown: it was finally destroyed by fire in 1698.

York stairs.

That piece of Architecture which is situated on the Thames at the end of Buckingham Street in the Strand, was originally a water-gate in the middle of a long embattled wall, skirting the gardens of the Duke of Buckingham on the river side; and was erected by Inigo Jones in 1626. The façade of this building, next to the street, consists of a semicircular arch in the centre, for a passage, and an aperture of a similar form on each side for a window; the crowns of these are of equal height from the pavement, but as the middle arch is wider than the others, its imposts are lower than theirs, which is a great defect; the face of each pier is ornamented with a pilaster of the Tuscan Order, and, over these, is a general horizontal entablature with stone balls placed as ornaments on its top. In the direction of the length of the passage through the centre, are two semicircular arches on each side, springing from imposts, and resting on a small pillar in the middle. The façade next to the river consists also of three semicircular arches; in front of the four piers on which they rest are four half-columns of the Tuscan Order attached to the wall; the two in the centre stand on the top of the flight of steps which leads from the passage down to the water, and the two others on plain pedestals. The imposts of the three arches are all in one horizontal line; the faces of the piers are rusticated to resemble rough masonry, and there are square blocks also rusticated, at intervals, on the shafts. The columns support an entablature which is broken above their capitals; and over the archway is a pediment formed by a segment of a circle, and having its tympanum ornamented with a shield, for which the horizontal cornice is interrupted.

Church of St. Paul, Covent Garden.

The Church of St. Paul, in Covent Garden, was originally built by Jones, in a style resembling that of the present edifice, which is a restoration executed under the direction of Mr. Hardwick; the old building having been destroyed by an accidental fire in 1795. The Architect seems to have intended to exhibit here the proportions of the Tuscan Temples as they are described by Vitruvius; and the whole building may be considered as very well appropriated to its situation, among the huts of a market-place, which it may be said to resemble in form; it must also be considered as, perhaps, the only existing specimen of an ancient Order, and on that account it is interesting. The plan is a rectangle 133 feet long, including the depth of the portico or pronaos, and 60 feet wide, and, contrary to the general practice in Churches, the altar is at the Western extremity; the height from the ground to the cornice is 35 feet. In front of the pronaos are two columns of the Tuscan Order between the antæ pilasters; all these have considerable diminution, and the sides of the shafts are curved in the vertical direction; the entablature consists of an architrave and cornice, and the latter is supported by cantilivers, or timbers, projecting as much as one-quarter of the height of the column. The façade is crowned by a pediment, the height of which from the horizontal cornice is 21 feet, or nearly one-quarter of the whole horizontal extent of the entablature.

Masonry was thus employed in the time of Inigo Jones for the public edifices of London, but the mansions of the Nobility were then merely of brick, and the houses of the citizens of timber; in the reign of Charles I., however, stone houses were built in London, and the Earl of Arundel was almost the first who introduced the practice of building in that material.

hedral of Paul.

Soon after the time of Inigo Jones the fire, which destroyed nearly the whole of London, was the occasion of bringing forward the talents of Sir Christopher Wren, who, in reedifying the City, had more opportunities of displaying his skill in Architecture than any individual before or since. Besides the restoration of a considerable number of smaller Churches, that distinguished scholar as well as artist, whose mathematical discoveries have merited the notice of Sir Isaac Newton himself, had the glory of erecting the Cathedral of St. Paul, in London, which, next to that of St. Peter, at Rome, is the most magnificent edifice in the modern World. The plan of the building is similar to that of the generality of the Christian Basilicæ; *viz.* a Latin cross; and, in the disposition of its interior, as well as its exterior form, it bears considerable resemblance to the Church of St. Peter, from which, indeed, the idea of the construction is acknowledged to have been borrowed.

Two rectangular parallelograms on the plan cross each other at right angles; the length of the principal one from East to West is 480 feet, measuring from the top of the steps before the Western front to the exterior of the wall at the Eastern extremity; at this end of the building is a hemicylindrical recess, which extends 20 feet further than the wall and contains the altar, so that the whole length is 500 feet, exclusive of the great flight of steps in front; and the general breadth on the exterior is 125 feet. The length of the transverse rectangle from North to South is 250 feet, not including the portico at each extremity, which projects 20 feet further; its breadth is 125 feet; and the centre of the intersection of the parallelograms is 280 feet from the Western front. On each side of the building, at the Western end, is a square tower, one face of which coincides with the plane of the Western front, but on the Northern and Southern, the faces project about 27 feet beyond the general walls of the building, making the whole breadth of the Western façade equal to 180 feet. In the rentrant angles situated between these towers and the main building are formed two Chapels, each 50 feet long and 20 feet broad, open towards the interior of the nave, on which side is a great semicircular arch resting on four columns, two under each foot.

The exterior of the whole building consists of two Orders, one above the other, and the lower stands on a basement 10 feet above the ground on the Western side, where a magnificent flight of marble steps, extending the whole breadth of the front, leads to the pavement of the Church. From this pavement to the top of the entablature of the lower Order, the height is 50 feet, and from this to the top of the entablature of the upper Order, 40 feet; so that the height of the horizontal entablature of the body of the Church from the ground is 100 feet. The Western façade is ornamented with a magnificent portico consisting of twelve columns, in couples, of the Corinthian Order; above their entablature are eight columns, also coupled, and of the Composite Order, besides four pilasters; these support an entablature, above which, and extending over the twelve pillars, is a pediment, the tympanum of which is adorned with sculpture. The Northern and Southern extremities of the transept have porticos, consisting each of six fluted, Corinthian columns, disposed in a segment of a circle on the plan, and crowned by a half-dome, which rests against the wall of the building.

Within the centre of the Western façade is a porch 50 feet long and 20 feet wide, and opposite the interval of the two middle pairs of columns is the grand doorway, leading to a vestibule 50 feet square, which is marked by four piers placed at the angles; the tops of the piers are connected by semicircular arches, and under these are coupled columns detached in front of the piers. The body of the Church is divided into three aisles by rectangular piers, ornamented with pilasters and supporting semicircular arches; and on each side of the porch and vestibule is a passage which leads directly to the corresponding aisle. The Eastern extremity of the Church is also divided into three aisles by similar arcades, and this part is occupied by the choir and chancel.

The entrances on the Northern and Southern extremities of the transept lead each into a vestibule 25 feet deep, and equal in length to the whole breadth of the transept; each vestibule, as well as the nave and choir, communicates with the centre of the Church by three arched passages formed between two immense piers and the walls at the intersection of the arms of the cross: the interior surfaces of the eight piers coincide with the faces of an octagon, and the rentrant angles between the arches are filled up to the level of the crowns of the latter so as to form pendentives which end at top in the circumference of a horizontal circle. Above this is built a wall, in the form of a frustum of a cone, which terminates in a horizontal cornice, at the height of 168 feet from the pavement; from this springs the interior dome, which is of brickwork, 100 feet in diameter where it rests on the cornice, 60 feet high, and in the form of a paraboloid; its thickness is 1 foot 6 inches, and at the top is a circular aperture 24 feet diameter. On the hances of this dome, at 200 feet from the pavement of the Church, rests the base of a cone of brickwork 94 feet diameter at bottom and 85 feet high; the cone is pierced with apertures, and ends, at top, in a vault formed like an hyperboloid, with a circular aperture 12 feet in diameter near the vertex; the top of the cone is 285 feet from the pavement, on it is a lantern 55 feet high, terminated by a hemisphere, and above this is a ball and cross. On the sides of the cone are timbers raised to support the exterior dome, which is made of oak; its base is 220 feet from the pavement, and its crown coincides with that of the cone; its figure is nearly that of a hemisphere, the radius of curvature of its profile being 57 feet, and the centres in a horizontal diameter passing through the foot of the dome. To prevent the cone and the interior dome from exerting a lateral thrust on their supports, a circular groove was cut horizontally in the masonry round their common base, and at three other places at different heights on the exterior of the cone; in these were placed strong iron chains, and the grooves were filled up with melted lead.

The pavement of the Church is of marble, and in the ceilings are formed hemispherical cupolas; all the arches are of stone, but the spandrils are filled with brickwork, and the interior surface of the lower dome, over the centre, is ornamented with paintings.

On the exterior of the building the intervals of the columns and pilasters are occupied by niches or windows with semicircular or horizontal heads, and crowned by pediments; the entablature of the inferior Order is quite plain, except that there are modillons under the corona; and in the frize of the superior Order are high modillons which seem to support the cornice. Each arm of the building is covered by a pediment-roof, and at the extremities on each face are acroteria supporting statues.

Above the roof of the building, is a cylindrical wall, 146 feet in diameter and 25 feet high from the ridge; this surrounds the lower part of the conical wall which rests on the eight piers at the intersection of the arms of the cross; its exterior is quite plain, and it is perforated by two courses of rectangular apertures. Above the wall, is a circular range of thirty-two Corinthian columns, 40 feet high, including their bases and capitals, and supporting an entablature; between the columns, are niches with semicircular heads, and the entablature is crowned by a balustrade. Vertically over the base of the cone, is raised another cylindrical wall, the upper part of which appears above the balustrade; this part is ornamented with pilasters attached to its exterior circumference, and between the pilasters are two tiers of rectangular windows; the exterior dome springs from this wall. The lantern at the top of the dome is of an octangular form; its exterior is adorned with Corinthian columns, and round its base is an iron balcony.

The towers at the extremities of the Western front are 220 feet high and ornamented with Corinthian pilasters; each terminates above the roof of the Church in an open lantern, the lower part of which is surrounded by Corinthian columns, and the upper part by small buttresses which rest upon the entablature of the lower part. A plan, elevation, and section of this Cathedral is given in pl. xxiii.

We must refer to the *Parentalia* for a description of the manner in which the walls of the old Cathedral were demolished and those of the present one were raised; the details are interesting and highly instructive to every one engaged in the practice of building.

This edifice may, for elegance of design, bear comparison with the Cathedral of St. Peter, at Rome, though it is far from being so large; and it even has some advantages over that celebrated structure. The horizontal entablature is less broken, though this bad taste has been carried much too far. The top of the dome is three times as high above the surrounding ground as the entablature of the general roof, while that of St. Peter's Church is little more than twice the height of the roof; consequently, the former dome is better seen by a spectator on the exterior, and appears more like what it ought to be; *viz.* the principal feature of the building. It must be acknowledged, however, that the interior faces of the walls present a naked appearance, and will require much embellishment from ornamental sculpture before they will harmonize with the richness of the exterior. A great defect also arises, in the interior, from that want of connection which is caused by the arcades interrupting the entablatures; and the archivolts of every two of the eight arches which support the dome, meeting together at their lower extremities, have the appearance of standing on points, and thereby excite a perception of weakness, which is not the less a fault for being only apparent.

In buildings of similar forms, it is evident that some criterion may be formed of the comparative merit of their construction, by ascertaining the ratio between the area of the whole plan and the sum of the areas of the horizontal sections of all the piers, walls, and pillars, which serve to support the incumbent mass; for that building which exhibits the greatest ratio between those areas must be the one in which the effect has been produced by the fewest means. Now, the Churches of St. Peter, at Rome, St. Mary, at Florence, and St. Paul, at London, are nearly similar buildings; and we borrow from Mr. Joseph Gwilt's description of the latter the following Table of their proportional areas.

	Whole areas in English feet.	Area of points of support.	Ratio.
St. Peter.......	227069	59308	1 : 0.261
St. Mary.......	84802	17030	1 : 0.201
St. Paul	84025	14811	1 : 0.170

The merit shown in the construction of the above edifices, which is inversely proportional to the numbers in the last column, will, therefore, be respectively in the proportion of 17, 20, and 26, nearly. But if vertical sections be made from North to South through the transepts of those Churches, the case will be found to be different; for the proportions between the external and internal areas of such sections are, according to Mr. Gwilt, as follows:

St. Peter........ 8325 : 10000
St. Mary........ 8855 : 10000
St. Paul .... 6865 : 10000

Hence it appears that St. Paul's Church is far inferior to the others in its interior capacity, which, however, is unavoidable, on account of the sides of its conical dome having considerable obliquity to the horizon, whereas the domes of the other Churches rise nearly vertically; consequently, they have less horizontal thrust towards the exterior, and require less mass of pier to resist it.

St. Stephen's, W brook.

Besides the great work we have just mentioned, Sir Christopher Wren designed or executed most of the public buildings of his time; but he is particularly distinguished on account of the applications he made of the Roman Architecture in his Churches. We have already had a specimen of his taste in this respect, on a great scale; and we purpose to add a short description of St. Stephen's Church, in Walbrook, which was executed by the same artist, and is remarkable for the elegance of its interior ornament.

Its plan is a rectangle, 82 feet 6 inches long and 59 feet 6 inches broad, with a semicircular recess at the Eastern end. It is divided longitudinally into five aisles by four rows of Corinthian columns on pedestals; but near the centre the places of four columns are unoccupied, and on the entablatures of the columns which are left, at the angles of a regular octagon, are raised eight semicircular arches, in the spandrils of which are pendentives forming the circular base of a dome, which rises above them in the shape of a segment of a sphere. The surfaces of the pendentives and of the interior of the dome are beautifully ornamented, and on the open top of the dome is an elegant lantern. The ceiling over the middle aisle from East to West is vaulted with groined-work;

the other parts of the ceiling are horizontal, and formed in panels by the entablatures which rest on the columns. This Church owes all its reputation to the merit of its interior, for the exterior is mean, and the situation of the building among the neighbouring houses is extremely confined.

Mary, oolnorth.

The Church of St. Mary Woolnorth, in Lombard-street, was executed by Hawkesmoor, a pupil of Sir Christopher Wren, and, for the elegance of its interior, is unrivalled by most of those built by that great Architect himself: a description of it is given by Mr. Gwilt, in Britton's *Account of the Buildings in London*, from which we have made the following extract. The plan of the interior is nearly a square, with its North-Western and South-Western angles truncated for the introduction of stairs: twelve fluted Corinthian columns are disposed on the sides of an inscribed square and coupled at the angles, and above them is an enriched entablature. The square space which they enclose is continued above them, and forms a clair-story pierced on each side by a semicircular window: the height of this story with its entablature is equal to half that of the lower Order, and the total height of this central part of the Church equal to its extreme width. In the Eastern end of the Church is a square recess for an altar, covered by a semielliptical ceiling; and on the Northern, Southern, and Western sides are galleries judiciously managed, so that they do not interfere with the simplicity and elegance of the general design.

The exterior is picturesque, and, though far from being in good taste, is well adapted to its situation and aspect; the principal front is towards the North, consequently deprived of the effect which would be produced by light and shade; and to compensate for this defect the artist has given to it great boldness of outline and prominence of feature, consisting of large semicircular rusticated niches standing on lofty pedestals and decorated with an Ionic Order. A block cornice reigns throughout the building, and the central part of the Northern front is surmounted by a balustrade. The same Architect executed the Church of St. George, Bloomsbury, the Corinthian portico of which is esteemed among the finest in London.

eples cuted by C.Wren.

The lofty steeples which frequently crowned the towers of the Gothic Cathedrals continued to be raised over Churches when the Roman style had superseded that which before prevailed, and appear to have been considered as an essential characteristic and ornament of an Ecclesiastical edifice. Sir Christopher Wren, who almost invariably employed the Italian or Roman style in the Churches he built, raised his towers from the ground in front, and placed on them steeples of a pyramidal form and vast height, which he decorated in a manner corresponding to the Architecture of the body of the Church as much as their tapering forms would permit.

ride's.

Of the towers which he built, the most remarkable is that of St. Bride's Church, in Fleet-street, the whole height of which is 226 feet, while the height of the body of the Church from the ground to the cornice is only 37 feet. The lower part resembles a very tall, quadrangular pedestal standing on a great plinth; in this is the doorway, and in the dado is a great double panel containing a rectangular and a circular window. Above the cornice of this dado stands a second pedestal, in the dado of which is a semicircular-headed window, and on each side are two Corinthian pilasters supporting an entablature and a pediment in the form of a segment of a circle, and the ceiling of the interior of this story is a vault in the form of a paraboloid. Above this second pedestal, if it may be so called, are four stories, octagonal on the plan, and diminishing in diameter successively upwards; in each face of these is an open semicircular arch springing from imposts, with a pilaster at each angle, standing on a podium and supporting an entablature; the pilasters in the lowest story are of the Doric Order, and those in the three upper ones are of the Ionic Order. Above the highest story is an octagonal pedestal supporting a pyramidal obelisk, which terminates in a ball: a winding staircase in the interior leads from the top of the rectangular part of the tower to the foot of the obelisk.

The arched openings give a great degree of lightness to the upper part of the fabric; and, in order to afford sufficient security, the stone piers in every story are connected by iron bars extending horizontally through the spire; also iron cramps and chains are imbedded in lead within the stonework in several places.

This spire exceeds in height that of any other Church executed according to the Roman Orders of Architecture, and very few of the Gothic spires are so lofty. Before the Church was struck by lightning, in 1764, its height from the ground was 234 feet, and, in repairing it, it was reduced to its present dimensions. See pl. xxiii.

Bow Church.

The steeple of Bow Church, which was also built by Sir Christopher Wren, rises from the ground in front of the Church to the height of 197 feet. The lower part is a square tower 83 feet high, and the length of each side on the plan is 32 feet 6 inches; at the foot is the doorway, which is contained within a semicircular-headed recess. Above this are three stories, each 38 feet high; the first is raised on a square plan, but is ornamented with coupled pilasters of the Ionic Order, at the angles, and in each face is a semicircular-headed aperture, the archivolt of which springs from imposts; the second story consists of a hollow cylinder surrounded by twelve Corinthian columns, standing on a circular pedestal, and supporting an entablature and balustrade, above which are twelve arched buttresses supporting the base of an octagonal lantern; this is also surrounded by twelve small Corinthian columns, on the entablature of which is a square obelisk 38 feet high. A spiral staircase is carried up the centre of the steeple, from the entablature of the Ionic columns to the base of the lantern.

St. Dunstan's in the East.

The steeple of the Church of St. Dunstan in the East, by the same Architect, is remarkable for its singular elegance, and because it is an excellent imitation of the Gothic style. It is raised from the ground upon a square base, 20 feet each way, to the height of 96 feet, and has, at each angle, a diagonally-placed buttress, terminating in an octagonal pinnacle, 29 feet 6 inches high; this tower contains three stories, in the lowest is the doorway, in the second, a window, and, in the third, an open aperture; each is terminated by an equilateral pointed arch. Above the roof of the tower, and from the four angles, are raised, to the height of 29 feet 6 inches, four arched ribs of stone, which meet over the centre, and form the base of an octagonal spire, the height of which is 54 feet 6 inches: the whole weight of the spire is borne by these arched ribs, and the space included by them is entirely open.

The use of bells to notify the hours of prayer affords a just reason for employing a turret above the Church, when it is not convenient to have a detached building, like the Campanile in Italy, for that purpose. But the great height which is usually given to steeples seems quite unnecessary, except, perhaps, in the country, where such objects may serve to mark the situation of the consecrated building, which might otherwise be unperceived by the traveller. We know but of one example in England in which the bell-tower is detached, and this is the Church of St. George, Bloomsbury, in London; in the same building there seems to have been an effort to make the spire harmonize with the Roman style displayed in the Church, but the success has not been such as to encourage any subsequent attempt to obtain that end.

Royal Exchange.

In the principal commercial cities of Europe, public places have been built in which the merchants assemble for the purpose of transacting business, as in the time of the Roman Empire they met in a part of the Forum or Basilica; and the Royal Exchange in London is destined for this purpose. It was originally built by Sir Thomas Gresham, in 1567, but being destroyed in the great fire of 1666, the present edifice was erected in 1669 by Mr. Jerman, one of the city surveyors. It consists of an arrangement of buildings enclosing a rectangular peristyle or piazza, 144 feet long, and 117 feet wide; this is surrounded interiorly by semicircular arches, springing from the abaci of the columns, which are of a Tuscan Order, and quadrupled at the four angles: the corridor between the arcade and the buildings is covered by a groined vaulting, formed by the intersections of hemicylindrical arches, and having the ridges ornamented by ribs which spring from grotesque heads on the walls, and in the interior spandrils of the arcade. Above this arcade is another, springing from imposts, on piers, the fronts of which are ornamented with attached Ionic columns standing on pedestals, and between the columns are windows or niches containing statues; the whole is crowned by a balustrade, and over the centre on each side of the court is a pediment in the form of a segment of a circle. In the centre of the area is a statue of Charles II., on a pedestal 8 feet high.

On the Northern and Southern sides of the exterior of the building, is a row of semicircular arches springing from piers, and forming the front of a covered gallery extending along each of those faces. The story above contains a row of large rectangular windows, between which are pilasters of a Composite Order supporting an entablature, and above this is a balustrade crowning the building. In the centre of the Southern front is the principal entrance, under a portico 70 feet long; here four lofty Corinthian columns are attached to the piers, and support an entablature; and between the two middle columns is a semicircular-headed gateway, the crown of which is 31 feet from the ground; on each side of this, and between the outer columns, are small doorways with curvilinear pediments, and above are niches containing the statues of the Kings Charles I. and II.

The old tower above the entablature of this front has been taken down, and the present one, which was executed by Mr. Smith, the Architect to the Mercers' Company, is of a different character. The whole length of this façade is 210 feet, and the height from the general pavement to the cornice 41 feet.

The entablature of the Southern portico, not forming part of that on the wings of the same façade, is the principal defect in this building, which nevertheless possesses a certain degree of magnificence, and remains a good specimen of the Architecture of the XVIIth century.

CHAPTER V.

Architecture of England during the XVIIIth Century.

French and German style introduced into England.

In the beginning of the XVIIIth century a taste for the style of building practised in France and Germany, which had been probably introduced by William III., prevailed, for a time, very generally in England, and is exhibited in many of the mansions of that period, particularly in the British Museum, London, and in Blenheim House, Oxfordshire. The façades of such edifices present many of the features of the worst style of Italian Architecture; the columns are of unequal heights, and, consequently, the entablatures on different levels, which give to the different parts of the edifice the appearance of so many distinct buildings instead of the members of one body; the sloping roofs rise to a considerable height above the walls, and the pavilions are crowned by open turrets, profusely ornamented with columns or pilasters, and strengthened by scroll buttresses totally destitute of utility. Lastly, in the interior disposition of the mansions of this period the communications with the different apartments are very defective; instead of a separate access to each, it is often necessary to get at one by going through several others.

Blenheim House.

Blenheim House, executed by Sir John Vanbrugh in 1715, may be considered as a specimen of the style of building of which we have been speaking. Its plan consists of three principal parts, each of a rectangular form, with their longest sides in the direction of the breadth of the building; these are connected together, near the principal front, by a corridor with a vaulted ceiling, and by a suite of apartments next to the garden front. Its whole extent in length is 350 feet, and in breadth 200 feet.

The central division contains two grand vestibules, of which that in the principal front is 58 feet long, and 42 feet wide, and the other, in the garden front, 40 feet long, and 34 feet wide; each of these has a portico consisting of four Corinthian columns, and a detached pilaster in the line of columns, at each extremity. One of the extreme divisions is a grand gallery, the length of which is 200 feet, and its mean breadth 27 feet; it consists of a centre in the form of a parallelogram, with a semicircular projection in front, a square wing at each extremity higher than the rest of the division, and two curtains connecting them. The third division is of the same form, but in its centre is a vestibule, which falls at the extremity of the corridor, and on each side is a bed-room with its anteroom, wardrobes, &c. On each side of the vestibule belonging to the garden front, is an antechamber, a withdrawing room, and a grand bedchamber; and on each side of the central division, between this suite of rooms and the long gallery, is an open court of a rectangular form, 43 feet 6 inches long, and 32 feet 6 inches wide; between this and the vestibule in the principal front are a dining-room and stairs leading to the upper story; on one of the long sides of the court is the corridor, and on the other two sides are dressing-rooms and closets. In each of the rentrant angles, between the corridor and the wings of the building, next to the principal front, are closets, dressing-rooms, &c., disposed upon the circumference of the exterior wall, the plan of which is in the form of a quadrant of a circle, concave outwards.

The columns which support the roof of the portico are 40 feet high from the pavement, and above them is an entablature with a pediment; within this height are two stories, of which the lower contains three doorways, and in the upper are semicircular-headed windows: the piers between the doors and windows very little exceed in breadth that of the columns which stand before them, so that the front wall of the vestibule scarcely appears, and the windows themselves are ill proportioned, being much too broad for their height. Over the vestibule a tower is carried up above the roof of the adjoining part of the building, and crowned by a second pediment. On each side of the portico, and between it and the quadrant, the face of the building is ornamented with three Corinthian pilasters, standing on a podium, the top of which is on a level with the pavement of the portico; the pilasters are of the same height as the columns of the portico, and they support an entablature, above which is a continued pedestal with statues; this part of the building contains two stories, the intermediate floor being on the same level as that within the portico. On the face of each quadrant are half-columns of the Tuscan Order, 21 feet high from the podium; these support an entablature on a level with the floor of the upper story under the portico; and above this is an Attic, crowned by a balustrade, the coping of which coincides with the level of the tops of the capitals of the columns and pilasters. At the extremity of the quadrant is a square pavilion, consisting also of two stories, in which are semicircular-headed windows, and the face of the wall, up to the roof of the second story, is rusticated with horizontal grooves only: above this is a turret with short pilasters in front, and open semicircular-headed arches.

Of each wing of the building the face, which is parallel to the front of the portico, is divided vertically into three parts, that in the centre projecting a little beyond the others, and being crowned by a pediment; and all the angles are ornamented with rusticated pilasters. In the face of the pavilion are two stories, the lower one lofty, and containing semicircular-headed windows, the upper one low, with square windows. The plinth of the wings is lower than the general podium of the body of the building, and the entablature over the second story is on a level with that of the half-columns in the quadrants: above this is a balustrade, and over the centre is an octagonal tower, having segmental pediments on four opposite faces; the turret is carried up above these pediments, and ends in a cone and ball.

Notwithstanding the faults of this building, particularly the want of unity in the design, its magnitude causes it to present a majestic appearance, worthy of the residence of the great Duke of Marlborough, for whom it was built. Sir John Vanbrugh also built Castle Howard in Yorkshire, for the Earl of Carlisle: this edifice is 660 feet long; one of its faces is ornamented with Doric pilasters irregularly distributed; the other with Corinthian pilasters at equal distances from each other, and the whole is crowned by a large cupola.

About the same period the domestic Architecture of England was destined to receive considerable amelioration from the genius of the Earl of Burlington, who, abandoning the caprices of the French School, cultivated a purer style by the contemplation of the remains of ancient Architecture in Italy, and a diligent study of the writings of Palladio. In the year 1717, or 1718, he made designs for the improvement of the mansion built by his father in Piccadilly, which were afterwards executed, probably under the superintendence of Mr. Colin Campbell, an Architect by profession at that time. Since this building exhibits a specimen of the style of Architecture subsequently employed to a considerable extent in the mansions of the Nobility, we proceed to show its character by a brief description.

Burlington House.

It consists of an arrangement of buildings occupying the Northern, Eastern, and Western sides of a court, 122 feet square; on the Southern side is a colonnade of a form nearly semicircular, with its concavity facing the North, and through the centre of this is the grand gateway leading from the street. The dwelling-house, which is on the Northern side of the Court, consists of a rectangular centre, 78 feet long from East to West, and 51 feet wide, and of two wings, each 26 feet broad, projecting 13 feet in front of the centre towards the South. On the Eastern and Western sides of the Court are two rectangular buildings, each 82 feet long from North to South, and 45 feet wide; these are connected with the main building by passages, and contain the offices and servants' rooms.

The Southern façade of the principal building is divided into two stories, of which the basement is rusticated with vertical and horizontal grooves; the doorway is in the centre, and there are four rectangular windows on each side. The upper story over the centre of the building is ornamented by half-columns of the Ionic Order, supporting an entablature broken over each column; and between every two columns is a rectangular window with triangular and segmental pediments alternately. The faces of both wings on this story have a pair of Ionic pilasters at each angle, with a continuous entablature, and between the pilasters is a broad *Venetian window*, as it is called, *viz.* one divided by small Ionic columns into three apertures, of which the middle one has a semicircular head. The whole building stands on a general plinth, and there is an ascent to the pavement of the lower story by steps; the entablature is crowned by a balustrade, the height of which from the ground is 48 feet.

The entrance gateway from the street has a semicircular head; and on each side are two Doric columns on pedestals, with cylindrical, rusticated blocks on the shafts; between each pair of columns is a hemicylindrical niche with a dome head; and above the entablature is an Attic extending over the two middle columns, and crowned by a pediment adorned with sculpture.

Villa at Chiswick.

The Villa belonging to the Duke of Devonshire, at Chiswick, was designed by Lord Burlington in imitation of Palladio's Rotunda at Vicenza.

Gibbs.

The Ecclesiastical Architecture of England, which had been affiliated by Jones and Wren to that of the Religious edifices of ancient Rome, received sundry improvements from James Gibbs, who was contemporary with the Earl of Burlington, and who has left a distinguished monument of his taste and skill in the Church of St. Martin in the Fields, which he completed in 1726.

St. Martin's Church.

Its plan is a rectangle, 79 feet 4 inches wide exteriorly, and 135 feet 6 inches long, not including the portico, which is 24 feet deep. This portico has six columns in front, besides one on each flank between the front row and the antæ pilasters, and all the columns resemble those of the Temple of Jupiter Stator. The

Church is divided into three parts by two rows of Corinthian columns standing on pedestals which raise their bases just above the pews; the columns are not connected by a continued entablature, but have blocks above their capitals in the form of portions of an entablature, from the cornices of which spring semielliptical arches crossing the nave, and others of a semicircular form in the direction of the length of the Church; semicircular arches also extend across the side aisles.

The nave of the Church terminates Eastward in a recess formed, on the plan, by two quadrants of circles and a rectangular part between them; the anterior part of this recess is covered by a portion of a spheroidal vault, and the part beyond by one of an elliptical form. The arches over the side aisles rest on corbels against the walls, and pendentives are formed which serve to support a range of coved vaults over each aisle. The soffit of the portico is richly ornamented with lacunaria, and that of the interior of the Church with paintings.

The exterior of the side walls is ornamented with attached pilasters of the Corinthian Order, standing on a podium, on a level with the pavement of the portico, and the entablature is crowned by a balustrade. Between the pilasters, are two tiers of windows; the upper, which are taller than the lower, are terminated by semicircular heads, and the others by flat segments; the jambs and archivolts of both are rusticated. Both the Eastern and Western extremities of the Church are terminated by pediments, and in the middle of the Eastern end is a large window divided into three parts by Ionic columns; over the two side apertures is an entablature, but that of the centre is covered by a semicircle which springs from the entablature as an impost.

The height of the Church, from the foot of the podium to the top of the pediment, is 58 feet 6 inches. Over the vestibule at the Western end of the Church, is a tower raised on a square base and ending in an octagonal spire, the whole height of which from the foot of the podium is 185 feet; the part immediately above the pediment is plain and resembles a pedestal, in the dado of which is a circular aperture on each side; above this is a division containing a semicircular-headed louvre, with two Ionic pilasters on each side, supporting an entablature; still higher is an octagonal lantern with a semicircular-headed aperture on each face; and in front of the piers are attached Corinthian columns, the entablature of which is crowned by the spire, which is of a pyramidal form and ornamented with panels.

The Churches of this period differ from those erected by Sir Christopher Wren in having a portico at the Western extremity, and in the steeple being raised over the body of the building, so that it appears to stand on the roof instead of resting on the ground; the propriety of this situation of the steeple may be questioned, but from the roof of the portico being a continuation of that of the building, as is the case in these Churches, there results a unity of composition, which is one of their greatest merits, and gives them a character approaching nearly to that of the Religious edifices of the Ancients.

St. George's, Hanover-square. The Church of St. George, in Hanover-square, by the same artist, resembles that of St. Martin, and, on the exterior, it may, perhaps, be said to equal the latter in merit; but the same praise cannot be paid to the interior, where the rich Composite Order is placed immediately above the simple Tuscan, while the organ-gallery is supported by Ionic pillars; thus three different Orders are employed in the same building in circumstances causing them to offend against the laws of simplicity and unity.

Somerset House. The Roman Architecture in England may be said to have arrived at perfection in the latter part of the XVIIIth century; and one of its noblest monuments is Somerset House, which was begun by Sir William Chambers, in 1776, on the site of a Palace built for the Protector, Edward Duke of Somerset, about 1547; this immense pile is almost wholly occupied by Public Offices, but it is not, even now, entirely finished.

The ranges of buildings are disposed on the four sides of a rectangular court, the interior length of which is 319 feet from North to South, and breadth 224 feet; the Northern side is separated from the others by a road 42 feet broad, and directed from East to West, with an arched gateway at each end.

The grand entrance is from the Strand through a triple passage, of which that in the centre is between two rows of Doric columns, coupled in the direction of the length of the passage. On one side of the entrance is the vestibule leading to the apartments of the Royal Academy, and on the other, that which leads to the apartments of the Royal and Antiquarian Societies: all the other buildings, and the remainder of this range, contain various Government Offices, in which there is nothing remarkable except the hall of the Navy Office on the Southern side of the court; this is 57 feet long, 37 feet wide, and its ceiling, which is flat, is supported by eight columns.

The Northern façade, or that which is next to the Strand, is 133 feet long, and consists of three stories; in the centre of the lowest are the passages before mentioned, the entrances to which are separated by two piers, and crowned by semicircular arches: on each side are three semicircular-headed recesses, containing windows, the entablatures of which are supported by Doric columns, and crowned by pediments; the height of this story, with its entablature, is 25 feet 8 inches; the piers, voussoirs, and spandrils are all rusticated, and a simple plinth runs along the foot of the façade. Above this story are two tiers of windows, of which those in the lower tier have entablatures supported by Ionic columns, the upper windows are square, and are surrounded by plain architraves; between these windows, the walls are ornamented with three-quarter columns of the Corinthian Order, standing on plain pedestals, between every two of which are balusters; the height of the columns in this Order is 23 feet of the pedestals, 3 feet 4 inches, and of the entablature, 5 feet. Over the centre of the façade is an Attic story, with four statues in front and two oval windows; and the rest is crowned by a balustrade, the coping of which is 62 feet above the ground. The interior façade of this part of the building is similar to that which has been already described.

The interior faces of the buildings, on each of the other sides of the quadrangle, are broken vertically to form a centre and two wings, which have small projections beyond the faces of the curtains connecting them; the lowest story of the whole, and the upper stories of the curtains, are rusticated; and there are three tiers of windows, of which the lower have semicircular heads, and the others are rectangular. The central part alone is ornamented with three-quarter columns of the Corinthian Order, and the whole is crowned by a balustrade.

The façade next to the river, which is 350 feet long, possesses a character of superior magnificence. Its divisions correspond with those within the Court, but in the centre of the upper story are Corinthian columns detached from the walls, with pilasters behind them; near each wing are columns and pilasters similarly disposed with a pediment above their entablature; and the centre of this line of building is crowned by a hemispherical cupola. Before this façade is a broad terrace supported by lofty arches and protected by a balustrade; in the centre is one great semicircular arch, for the admission of vessels from the river; and near each extremity is a watergate of a similar form, the piers of which are ornamented with rusticated columns.

The entrances, which are at the ends of the street within the Northern side of the quadrangle, consist each of three semicircular arches, of which that in the centre is higher than the others; on either side of this arch the rusticated pier is ornamented with a Doric column, having roughed blocks on the shaft, and an Attic base; and the entablature over the central arch is cut by the voussoirs, so that there appears only part of the architrave and frize with two triglyphs on each side, a deviation from propriety into which it is surprising that an artist of so late a period could have fallen. The cornice is uninterrupted, and is ornamented with modillons.

The Doric columns in the Northern entrance to the building have Attic bases, and the entablature is formed over each pair of columns only; the frize is decorated with ox-sculls instead of triglyphs, and there are dentels in the cornice. The ceilings above the passages are hemicylindrical, and the spandrils are pierced by arches crossing the three vaults at right angles. The spandrils and crowns of the vaults and the soffits of the arches between the columns are ornamented with panels and elegant fretwork margins. The central passage through the Northern building is much too narrow, and it has been observed that instead of the three, which at present exist, there should have been made one grand archway; this would, of course, have required a different kind of façade above; but one might easily have been designed in which such an entrance would have been consistent with equal convenience in the interior of the building.

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We are indebted to Sir William Chambers for one of the best written Works on what is called the decorative part of Civil Architecture. In this, the proportions of the Orders are detailed according to the Roman style with some just modifications, and a variety of elegant forms of the different members of an edifice are exhibited and described. We regret only to find in it an unworthy prejudice against the Grecian Architecture, with the character of which the author does not seem to have been acquainted; he even doubts the existence of any considerable remains of that Architecture in the Country of its birth, though during his life the magnificent edifices of Greece were delineated and made known to the World in the splendid publications of Le Roy, Stuart, and other artists. A convenient and elegant edition of Sir William Chambers's Work, enriched with notes, has been published by Mr. Joseph Gwilt; and an outline of the Grecian Architecture, which was much wanting to render the original Work complete, has been supplied by the same gentleman in an introduction.

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Sir William Chambers, in modifying the Tuscan Order, has made its general proportions nearly the same as those assigned by Vignola; the height of the column is by both made equal to seven diameters, but the English Architect has made the diminution rather greater, it being equal to one-sixth of the lower diameter; he has made his entablature equal in height to that of Palladio, *viz.* one-quarter of the height of the column; like Vignola he has made the architrave in one facia, whereas Palladio has divided it into two, which is rather complex for this Order; but he has lightened Vignola's cornice, and has placed above the corona a cymatium instead of the ovolo which occurs in the Italian example; the latter member he considers an improper finish, because it seems as if intended to support something above it where, however, nothing exists.

His Doric Order is like that one which Vignola has given with mutules in the cornice, except that he has judiciously given but one facia to the architrave. The other Orders hardly differ from those of Vignola either in proportion or ornament, except that they all have Attic bases: in the Ionic example, the architrave and frize are of equal height, and the former is divided into two faciæ separated by ornamented mouldings; in the entablature of the Composite Order he has given both dentels and modillons, the latter of which are similar to those in the specimen of the Order given by Palladio, the former rather larger.

Grecian Architecture introduced into England.

From Peacham's *Complete Gentleman*, we learn that Sir Kenelm Digby, in the reign of Charles I., brought some of the marble bases, columns, and altars from the ruins of the Temple of Apollo at Delos; and, at a later period, the travels of Messrs. Wheeler and Spon, in Greece, made the artists of England acquainted with the nature of the buildings yet remaining in that Country; but neither those relics of Grecian sculpture, nor the general descriptions of the edifices, seem to have had any influence on Taste at the time; afterwards, however, when the admeasurements of the ancient buildings of Athens were published by Messrs. Stuart and Revett, a revolution took place. The subsequent publication of the remains of Grecian Architecture in Sicily, Italy, and Asia-Minor seems to have confirmed that preference, and, down to the present day, the greater part of the English buildings are formed on Grecian models with slight modifications. The Work on the Antiquities of Greece, published by M. Le Roy, was, perhaps, the cause of a similar Taste being excited in France; but it was not till after the Revolution that the Grecian Architecture became general there: since that time it seems to have been adopted in almost every other part of Europe.

CHAPTER VII.

Characteristics and Examples of Modern Buildings.

This Chapter will be devoted to a consideration of the nature of such edifices as the present state of Society requires, and to the description of a few of the most important; chiefly those which have been erected in England since the commencement of the XIXth century. For elegant engravings and more ample details, the reader is referred to Britton's *Illustrations of the Public Buildings in London.*

General character of a Church.

An edifice consecrated to Religion should be capable of exciting the most solemn emotions; it should remind him who enters it of the presence of the Deity, and should aid the sentiments with which he is come to present his offering of prayer or praise. It should not only differ in its general form from a building intended for other purposes, but every member which, from necessity, must also enter into the composition of a private dwelling, should, in a Church, be on a large scale, and, from its embellishments, acquire an elevated character. Like every other Public building, it should be situated where access to it is easily obtained; in a city it should be as far removed as possible from the general line of the street, in order that the noise of passing carriages may not disturb the congregation, and it should be elevated a little above the level of the ground, on a substantial basement, with spacious steps at convenient places.

Modern Churches are, mostly, imitations of ancient Temples.

The practice of crowning Churches with domes, which extended from Italy to all other parts of Europe, seems to be abandoned in England, and with it the cruciform plan; we now generally construct our Churches, like the Grecian Temples, on a simple rectangle, with a regular portico in front, and a pediment-roof; but some kind of steeple is still retained and placed over one extremity of the building. The side walls are perforated by windows in two tiers; and those in the lower tier are always made short, because the galleries, for the sake of convenience, must be kept as low as possible. The body of the Church is generally divided into three parts, of which that in the centre is separated from the aisles by columns in two tiers; the lower Order supports the anterior of the gallery, and the upper supports the roof. The altar is enclosed by a balustrade or rail at one extremity, in a recess, the pavement of which is elevated a few inches above that of the Church.

Church of Ayott St. Lawrence,

One of the first Churches in the Grecian style is that which was executed by Mr. Revett, at Ayott St. Lawrence, in Hertfordshire. Its plan is rectangular, and there is a hemicycle at the Eastern end; in front is a tetrastyle, Doric portico crowned by a low pediment; and on each side is an Ionic colonnade, connecting the centre with an elegant cenotaph. This edifice was built near the end of the XVIIIth century; and since that time a considerable number of Churches have been erected in London, and in various parts of the Country, in imitation of different Grecian Temples, but generally with few of the enrichments which are found on the ancient models.

of St. Pancras,

The greatest example of this style in England is the Church of St. Pancras, erected by Mr. Inwood, in 1822, and which is nearly a copy of the triple Temple in the Acropolis, at Athens. Like that building, the plan of the present Church is a rectangle; at the Eastern extremity is a square projection on the Northern and Southern sides, and both these projections have flat roofs supported by Caryatides, exactly similar to those which ornament the Athenian Temple. The Eastern face of the Church is terminated by a semicircular recess, and over the Western extremity is a lofty steeple. The lower part of this consists of an octangular tower ornamented by eight columns, the capitals of which resemble those in the porches of the Temple of the Winds; above this is a similar but smaller tower, which is also surrounded by eight columns, and the whole is terminated by an octangular turret resembling the upper part of the same Temple. The Western front is enriched with a fine hexastyle portico, corresponding in its proportions and embellishments to that of the Erectheum; the Western doorways, and the upper windows on the three sides of the Church, are also constructed in conformity with the corresponding members of the Grecian Temple.

The Roman Architecture is also still employed to a considerable extent in England, in buildings intended both for Ecclesiastical and Civil purposes; the richness of the Corinthian capital and entablature rendering that Order convenient where the highest degree of magnificence is to be obtained. The Church of St. Mary le Bone, built by Mr. Hardwicke, in 1819, is one of the latest examples of this style, and in its plan it deviates considerably from the simplicity of those recently erected in London.

of St. Mary le Bone,

The direction of the greatest length of this Church is from North to South instead of from East to West, which is the general position; its breadth is 70 feet, and its length 122 feet, besides the depth of the portico, which is 18 feet 6 inches. This portico, which is on the Northern side of the building, is hexastyle, and 60 feet wide between the centres of the extreme columns; the columns, which are of the Corinthian Order, are copied from those of the Pantheon at Rome; and between the front row of columns and the pilaster attached to the face of the wall is a column at each extremity of the portico; the entablature is simple and crowned by a pediment. The front of the Church is 110 feet in extent from East to West, and this excess above the general breadth is caused by a wing projecting each way beyond the side walls of the Church; the wings are ornamented with Corinthian pilasters at the angles, and at the extremity of each there are two columns of the same Order standing on tall plinths in a direction perpendicular to the front. Within this front is a circular vestibule, on each side of which are the steps leading to the galleries. The opposite extremity of the Church is formed on three sides of an octagon, and has a large Venetian window in the middle face; on each of the others is a rectangular building, one serving as a side entrance to the Church and the other constituting the Vestry. The height of the Church from the ground to the cornice is 45 feet 6 inches; the top is surrounded by a balustrade, and over the Northern front there is a steeple, the height of which above the cornice is 74 feet. There are three entrances in front, with horizontal-headed doors; above these are semicircular-headed windows, and two tiers of the same kind of windows are formed in each side of the Church.

It has been justly observed that the portico of this Church, by facing the North, is deprived of the brilliant and diversifying combination of light and shade which it would have possessed in any other aspect; it consequently appears sepulchral, gloomy, damp, and cheerless. This disposition has been given to it in order, no doubt, that it may face the high road; but this advantage would have been gained, and the defects avoided, by placing the Church on the other side of the way, where also there would have been more space for it than its present localities afford. It has been observed also, that, in the interior, the twofold tier of galleries, the polygonal recess at the Southern end, and the decorations of the organ-case, being combined with those of the altar, produce an effect which assimilates more closely to the character of a Theatre than is generally thought consistent with that of a Christian Church.

In some of the most modern Churches of England an effort is made to copy the style of our Gothic Cathedrals; but notwithstanding the merit with which many of these have been executed, it is impossible that they should afford the mind an equal satisfaction with that produced by ancient buildings of the same kind, because they want the venerable character which age alone can give, and at once show themselves to be but imitations. Buildings executed on Grecian or Roman models are contemplated with more complacency, because no ancient examples of those styles, with which they may be compared, exist in the Country; the effect they produce on the mind is, therefore, nearly equal to that which would be excited by the view of works possessing a perfect originality of form.

Luke,
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The parish Church of St. Luke, Chelsea, executed by Mr. Savage, in 1824, may be considered as a good specimen of what is called the modern Gothic style. Its form is rectangular, and the interior is divided into a centre and two side aisles by seven acutely-pointed arches on each side, which spring from clustered columns; the vaulting over the central division is of masonry, and ornamented by cross ribs, diverging from the summits of the shafts, which are carried up the wall of the clair-story from the columns supporting the arcade below.

In front of the Western end of the Church is a square tower raised on four piers connected by pointed arches, of which the two lateral ones form a communication between the tower and an arcade on each side directed from North to South. On each side of the Church are flying buttresses extending over the roof of the aisle, to resist the lateral pressure of the roof, and between these are the windows. The walls both of the nave and aisles are crowned by perforated parapets, and there are two octagonal turrets at the Eastern extremity of the building; these are divided into several parts horizontally by mouldings, a circumstance which is considered as injuring the simplicity of the design.

The archway in the face of the Western tower is ornamented with a pediment moulding, and above it is a tall, pointed window divided by mullions and transoms; still higher is a window of similar form, the crowning moulding of which is adorned with crockets: lastly, the upper story is enriched with a perforated, embattled parapet and with panelling on the walls, and, above the four angles, are pinnacles ornamented with crockets and finials.

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In domestic Architecture the style of construction should be suited to the quality of the occupier of the building. The cottage of the peasant may be of the utmost simplicity, yet it should be made capable of protecting the inmates from the injuries of the weather, and its external form should be such as to render it an object not unworthy of the scenery by which it is surrounded. The dwelling of a man of moderate fortune should afford all possible conveniences with some degree of ornament. But the mansions of the Nobility, besides possessing superior strength and durability, should contain, in their interior, every circumstance that can contribute to the comfort of the proprietor, and both the interior and exterior should be adorned with splendid and tasteful decorations.

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The Grecian Orders were, soon after their introduction into this Country, employed by Mr. Holland in domestic Architecture, and one of the first examples is Melbourne House, Whitehall. In front of this building is a fine Grecian-Ionic portico projecting from the wall and consisting of four columns, which support a pediment-roof; but, from some inattention to the spirit of the ancient style, excusable only in a work erected when that style had been but little studied, we find on each side of the portico two columns of the same Order detached from the wall, and the general entablature broken to project over each, as in some of the Roman buildings. Columns so placed could only have been intended for ornament; but, in the Grecian Architecture, the destination of those members has always a reference to utility, and here, unless we suppose them to serve as buttresses, they appear to have no pretension to that quality. The portico leads to a circular vestibule surrounded by columns, which leave a gallery between them and the interior circumference of the wall, and crowned by a segmental dome: on the side opposite the entrance is a grand flight of steps leading to the body of the building.

Carleton
Palace.

Carleton Palace, which formerly stood in Pall Mall, was also a work of the same artist. Its general plan was rectangular, and in the centre of the façade was a grand and highly enriched portico of the Corinthian Order. In front of the building was a court separated from the street by a screen of coupled Ionic columns similar to those which adorned the Temple on the Ilyssus, near Athens, but with Attic bases; these columns were raised on a high podium, and supported an entablature only. At each extremity of the screen was an arched gateway.

The Royal
Palace in
St. James's
Park.

The new Royal Palace erected on the site of Buckingham House, does not seem by any means worthy of the Architecture of England in the XIXth century, yet, as some notice of the town residence of the Sovereign may be expected, we think it right to give a short description of it in this place.

The general plan of the main building is a long rectangle, broken by projections both towards the front and rear; and from the two extremities proceed wings towards the Park, at right angles to the body of the building, so that the Palace occupies three sides of a quadrangle. In both the façades of the edifice are two Orders of Architecture one above the other; the lower, on the side next to the Park, is Doric, and consists of fluted columns detached from the face of the building, so as to leave a corridor between them and the walls; above the corridor is a gallery protected by a balustrade. The central projection forms a portico consisting of four pairs of coupled columns of the Doric Order, and above their entablature are four pairs of Corinthian columns, supporting an entablature in the same horizontal plane with the general entablature of the building; this upper tier of columns is crowned by a pediment.

The upper part of both façades contains two tiers of rectangular windows, and, between the centre and extremities, each façade is interrupted by two of the projections before mentioned; the lower parts of these, on the side next to the Park, break the continuity of the colonnade, and each presents to the front a plain face, in which is an entrance; the upper part of the front of each of these projections is ornamented with two pairs of coupled Corinthian columns supporting part of the general entablature, and above this is an Attic in the form of a square turret, ornamented in front with panels; similar Attics crown the pavilions at the extremities of the building, and between the Attics is a balustrade over both fronts. The fronts of the two projections just mentioned contain, each, in the upper Order, one rectangular window cut down to the level of the gallery above the lower story, and over it is a small circular window, according singularly ill with the general style of the building.

The Architecture of the wings is similar to that of the façade next to the Park; in the lower part of each is a

Doric colonnade extending the whole length of the wing, and in the centre is a projection supporting Corinthian columns.

The garden front has a rusticated basement which is crowned by an architrave cornice; the central part of the whole façade projects in a semicircular form from the building, and, above the basement, the projection is ornamented with six Corinthian columns bearing a semicircular entablature, over which is part of a cylindrical wall ornamented with statues; the other four projections are rectangular, and each of their faces is ornamented with two pairs of coupled columns of the Corinthian Order.

A terrace extends along the whole of this front and is terminated at each extremity by an Ionic portico; the King's private dwelling-house adjoins the Palace on the Northern flank, and has, in front, a portico, under which the Royal carriage may enter. The approach to this part of the Palace is by a road along the interior side of the garden-wall, at the extremity of which, that is on the South side of Piccadilly, is a grand Triumphal Arch.

The majestic simplicity which should reign in such an edifice as this is destroyed by the narrow projections and the numerous apertures; but particularly by the contracted space allotted to the portico in the centre of the Eastern façade. In this front, also, the employment of the light Corinthian immediately over the Grecian-Doric Order is attended with too abrupt a change in the proportions to be consistent with the rules of harmony; the omission of the triglyphs in the entablature of the latter cannot but be highly objectionable, since the Order is thereby deprived of its essential characteristic; and the wings, by projecting so far towards the front, give the latter the appearance of a secondary instead of the principal object. The garden front seems to be in a better style than the other.

Civil structures for public service.

Buildings intended for the public meetings of the Legislative Body in a State, should be characterised by the highest degree of majesty and splendour, that they may correspond with the elevated rank of the persons composing it, and the importance of the subjects which are discussed within their walls. Their avenues should be spacious, and their interior should comprehend all the apartments necessary for the transaction of business relating to legislation.

The exteriors of the edifices which, in England, serve this great purpose cannot be considered as specimens of what may be expected to meet the eye of a spectator, on approaching the place wherein the Representatives of a great Nation hold their assemblies. One of them is hardly superior, in decoration, to that which encloses the Hall of a trading company, and the other, by the irregularity of its plan and the multitude of its windows, conveys rather the idea of a Hospital than of a Senate House. We, therefore, notice merely the building containing the Offices of the Council and Board of Trade, at Whitehall, executed by Mr. Soane, in 1826; and this may be given as an example of the latest style adopted in the public edifices of the Country.

The Council Office.

The plan of this grand pile is a rectangle, 315 feet long and 75 feet broad; the front is composed of a central part 150 feet long, and of a projecting pavilion 82 feet 6 inches long at each extremity; the whole length of the former part is ornamented with attached fluted columns of the Corinthian Order, and each of the pavilions has six columns of the same Order advanced at some distance before the wall. Six columns also adorn the front in Downing-street; the two remaining sides are connected with other buildings containing Government Offices.

All the columns stand on a stylobata which is broken under the pavilions, and the projections are connected by a balustrade in front of the stylobata of the curtain; the entablature is broken in a corresponding manner and is crowned by a balustrade. The stylobatæ of the front and side of the building form a reëntrant angle at their place of meeting, and the quoins of the pavilions are distinguished by pilasters having Corinthian capitals and plain shafts, which form a judicious relief to the fluted columns. The whole building is divided into two stories with horizontal-headed doors and windows, and above the entablature is an Attic. An oversight has been committed in disposing the plan of this edifice; for if a pavilion should be built at the Northern extremity, to correspond with that at Downing-street, it would fall into and disfigure the street of Whitehall.

To the same class may be referred those edifices which are intended to facilitate the transactions arising out of an extensive commerce, and the communications among the members of a State; and of the buildings executed in London on a great scale, for these purposes, we select for description the Bank of England, and the Office of the General Post. The Royal Exchange might have been introduced in this place, but, being the work of a former century, we have preferred describing it elsewhere.

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The Building which contains the public treasure of the State, and the Offices appointed for its management, should, by the splendour of its decorations, be an ornament to the city in which it stands, and by the solidity of its construction, an indication of the security which it affords to the valuable deposits made within its walls. The Bank of England, the destination of which is above expressed, is the work of Mr. Soane, who succeeded Sir Robert Taylor in the superintendence of its Architecture. It consists of a mass of buildings enclosed by a stone-wall, the plan of which is quadrilateral; at the extremities of the faces the wall is rounded, and recesses are formed in it, containing each two fluted Corinthian columns between pilasters, except at the North-Western angle, where, in the recess, are placed four fluted columns arranged on the arc of a circular segment with two plain columns behind them; and where, at each extremity of the segment, is a rectangular projection with two fluted columns of the same Order. The whole wall and its columns are supported by a plain basement and crowned by a general entablature.

The principal front is on the Southern side, in the centre of which are eight fluted, Corinthian columns resembling those about the Temple of the Sibyl at Tivoli; the face of the wall on each side of these is divided into three parts, of which that in the middle is ornamented with six attached columns, and that on each side with four pilasters; between these pilasters are three rectangular recesses with horizontal tops, and that in the middle is higher than the other two. The frize of the building is ornamented with an elegant fretwork, and the corona is supported by modillons, one over each column. Above the cornice, is a row of fleurons on cubical blocks, and at intervals among them are ornamented pedestals crowned with pediments, and having each face of their dado marked by three vertical grooves. In the centre of this front, the building rises a story higher than the entablature of the Order; the face of this Attic story is ornamented with pilasters, between which are recesses, and above the cornice is a parapet supporting a row of vases.

On the Northern side there is, in the centre of the enclosing wall, a recess containing two Corinthian columns between pilasters, and on each side of it a semicircular-headed doorway: one of these leads into a court of an irregular figure, on the right and left of which is a flight of long steps perpendicular to the face of the exterior wall; these lead to a pavement on a level with the floor of the Offices, and on the upper step is a screen consisting of four Corinthian columns, which support only their own entablature and a row of vases: opposite the entrance gateway is a Triumphal Arch leading to the interior.

In the centre of the Eastern side is a range of fluted Corinthian columns, behind which is a shallow recess, and, on one side, is a doorway leading also to the offices. In the centre of the Western wall is a recess with columns similar to that on the Northern side, and over this is a sort of Attic with five semicircular-headed apertures in front; above, and concentric with the intrados of each, is an ornamental groove terminating at the springing in a rectangular fret, and at each extremity of the Attic is a small pilaster ornamented with rectilinear grooves. On each side of the recess, and equally distant from it, is a doorway, vertically over which, and above the general entablature is, instead of a pediment, a curvilinear ornament ending in a scroll at each of the lower extremities. Within the entrance on this front is a vestibule having Grecian-Doric columns in the interior.

Between the Offices are quadrangular areas, and the fronts which look into one of them remain as they were executed by Sir Robert Taylor, with attached Corinthian columns; in another quadrangle the area is sunk below the general level of the pavement; the lower parts of the containing walls are ornamented with vermiculated rustics, and support an open arcade above the pavement.

The entrance on the Eastern side leads between several rectangular halls, on the right and left hand, to a rotunda or circular saloon, above which is a tambour containing the windows, and ornamented with Caryatides supporting a dome. The ceiling of the rectangular halls consists of hemicylindrical or segmental vaulting with panelling in the soffits, and, in some, the cylindrical vault is interrupted by a dome in the centre.

The Western and Northern sides of the building seem particularly intended for the reception of such valuable deposits as are made in large quantities; and the occurrence of casualties, at the time of making them, is entirely prevented by the carriages which convey them being made to enter within the enclosure and there discharge their contents; the interior of the former part, being not frequented by visitors, and only occasionally entered by the officers of the establishment, does not require much embellishment, and, accordingly, it is here that we find the simple Doric Order employed; the other parts, being open to the Public, are more highly decorated. A sober taste may, perhaps, condemn as fantastic some of the ornaments about the exterior of the building.

The new Post Office in London, by Mr. Smirke, is a splendid example of the Grecian Architecture applied to a modern Public edifice. The plan of this building is rectangular, and its front is about 400 feet long; in the centre is a projecting hexastyle portico, 70 feet long, with one column between each of the antæ pilasters and the front columns of the portico; the columns are of the Ionic Order, and resemble those at the Temple on the Ilyssus; they have Attic bases and fluted shafts, and stand on plain pedestals. At each extremity of the façade is a pavilion with four detached columns of the same Order in front; and on the side, two unfluted pilasters.

A continued podium reigns about the building, and there is an ascent to the pavement of the portico by a grand flight of steps. A general entablature crowns the whole edifice, but the upper facia only of the architrave extends over the curtains between the portico and pavilions; the frize is high and quite plain, and there are dentels in the cornice.

In the façade are two tiers of windows with horizontal tops; those of the upper tier in the curtains, and of both tiers, in the pavilions, are crowned by projecting cornices supported by consoles. On the sides of the building, there are three tiers of windows, of which those below are semicircular headed; those in the second tier are rectangular, and the faces of the piers between them have the appearance of broad pilasters with mouldings at the top; and the upper tier of windows is cut in the frize of the entablature of the building. The basement of this edifice is of granite, and the superstructure, of brick faced with Portland stone.

Situation and character of a Theatre.

A Theatre should be situated in some spot to which the inhabitants of the city may easily have access. According to Milizia, it should occupy a spacious area formed by the meeting of several principal streets, and should be surrounded by porticos or arcades of various kinds for the reception of carriages and for the security of pedestrians; the entrances and staircases should be so disposed that the interior of the building may be speedily filled and evacuated; and, above all, the part occupied by the auditory should be such as to permit all persons to see and hear the performers with nearly equal facility. The exterior of the edifice should, of course, be an indication of the agreeable entertainment which is to be expected within.

It is not often that all the circumstances requisite for a perfect Theatre can be obtained, but the principal cities of Europe may now boast of possessing some which unite most of the qualities necessary for internal convenience and external decoration: we must, however, confine ourselves to a description of one example, and we select the Theatre which was erected by Mr. Smirke, near Covent Garden, in the year 1809.

Theatre of Covent Garden.

The plan of the whole system of buildings forming this Theatre is a parallelogram, 209 feet long, and 166 feet wide, exclusive of the portico; the centre is occupied by the auditory and stage, which extend nearly through the length of the edifice from North to South; the staircases and apartments for the performers are on the Eastern and Western sides. The space appointed for the auditory is circumscribed by a parallelogram, 85 feet long and 64 feet wide, within which are three tiers of boxes arranged in the form of a horse-shoe, the extremity furthest from the stage being semicircular, and the sides in the direction of right lines converging to a point beyond the bottom of the stage; over the upper tier of boxes are galleries, also occupying the three sides of the auditory, besides an upper gallery at the extremity; and on the exterior of the boxes, in each tier, is a corridor by which access is gained to the particular seats. In the area included by the boxes is the pit, an inclined plane, lowest towards the stage, and on which the seats of the spectators are arranged in directions parallel to the breadth of the building; in front of the pit is the orchestra, a space for the musicians, 6 feet broad, and 42 feet long, which is equal to the whole interval between the two extreme boxes in the lower tier. The stage itself is contained within a rectangular area, 70 feet deep from the orchestra to the rear, and 82 feet wide; in front is the proscenium, 42 feet wide and 13 feet deep, bounded by the orchestra in front and the drop-curtain in the rear, and at each extremity are two pilasters painted to imitate Sienna marble: the floor of the stage is on an inclined plane rising towards the rear about 3 feet, on which at intervals are parallel grooves for the reception of the scenes, and on each side are recesses to contain the paintings. The interior of the auditory is superbly enriched with gilding; the boxes are supported by slender iron columns, fluted and gilt, and their interiors, as well as the sides of the pit, are decorated with representations of dark crimson drapery, producing a fine contrast to the brilliancy of the front. The middle of the ceiling is circular, and in the centre is a glory surrounded by golden lyres; from this centre depends a superb chandelier of glass illumined by two circles of gas-lights; the remainder of the ceiling is a light-blue sky relieved by delicate white clouds.

The principal façade is on the Eastern side of the building; in its centre is a grand portico of four fluted Grecian-Doric columns, elevated on a flight of steps and supporting a pediment; in the basement story is an arcade on each side of the portico, and the upper part of the building is decorated with representations of dramatic subjects, ancient and modern, in bas-relief. The grand entrance leads to a square vestibule, 37 feet long, and divided into three parts from North to South by two rows of piers. On the Southern side is the aperture leading to the principal staircase, which is 15 feet wide, between two rows of large porphyry columns of the Ionic Order; on one side of the staircase is the doorway leading to the auditory, and in front is an entrance saloon, ornamented with pilasters executed in porphyry. On the Western side of the Theatre, and corresponding to the grand staircase, is another leading to the King's saloon and private box, and a vestibule, the ceiling of which is supported by four columns, which also leads to the auditory. In the centre of the Southern side of the building are two grand saloons one above the other, and each 56 feet long, and 18 feet wide.

The entrance to the stage, and to the apartments appropriated to the performers, is in the Northern front; the latter consist of the dressing-rooms, the green-room, and managers'-room; there is besides a committee-room, a store-room, and, in the middle of the front, a large scene-room.

Characteristics of Hospitals.

The buildings appropriated to charitable purposes constitute one of the chief glories of the present Age; in England particularly, besides asylums for the aged and disabled, almost all the different modes of human suffering are provided against by establishments formed for their prevention or remedy; among which the Hospitals, for the cure of sickness and accidents, hold a distinguished rank. In these buildings every thing like magnificence of construction and richness of ornament would be quite misplaced, and their chief merit should consist in simplicity and convenience. The London Hospitals generally consist of buildings disposed on the four sides of a rectangle, and enclosing a considerable area, and the most considerable is that of St. Bartholomew, near Smithfield. In this, the buildings containing the wards for the patients occupy three sides of the quadrangle; each of them consists of four stories in height, and on each story are four well-aired wards; the fourth side contains the apartments of the principal officers and the committee-room. Behind one of the buildings is situated the Pharmacy and a Theatre for Anatomical Lectures.

St. Barth lomew's Hospital.

A custom prevails in the English Hospitals of placing the heads of the beds against the walls, which often brings them very near the windows, and, consequently, exposes the patients to the danger of taking cold. We know only one building in England in which a better disposition has been followed, and this is the School for the Blind, where the late Mr. Tappen, copying the method adopted in the great Hospital at Lyons, has placed the beds in pairs, with the heads of every two meeting in the middle of the room, so as to leave passages between the feet of the beds and the walls.

Bethlem Hospital.

The Bethlem Hospital, for the reception of lunatics, situated on the Surrey side of the Thames, consists of a line of building 569 feet long, and 60 feet high, and possesses every accommodation which can contribute to the comfort of persons in that unhappy state. It was built by Mr. Lewis, in 1812.

In the centre of the façade is a grand portico, 130 feet long, of Grecian-Ionic columns supporting an entablature and pediment, above which is a double Attic tower crowned by a plain dome; the columns stand on pedestals, and there is an ascent to the pavement of the portico by a flight of steps extending its whole length. On each side of the portico is a curtain, 141 feet long, terminating in a pavilion, 78 feet long in front; the face of the latter projects before the curtain, and is itself divided vertically into three parts, that in the centre projecting before the others: above each pavilion is also an Attic turret of an octangular form. The curtains and pavilions contain three tiers of plain, rectangular windows, and are crowned by a horizontal cornice of stone on a level with that over the portico.

The edifice is enlarged behind by two projections from the main body, one on each side of the centre, and a detached building has been erected behind each of the pavilions for the reception of criminal patients, or those afflicted with infectious diseases.

In the centre of the main building is a grand vestibule, behind which is the principal staircase, and on each side of the latter are apartments for the physician and steward; adjoining these, is a room in which the patients see their friends, and a large store-room. One vast corridor, adjacent to the front-wall, extends quite through the length of the curtain and pavilion on each side of the centre; this serves as a place of exercise for the patients, and along that side of the corridor which is next to the back-front are the cells. In front of each of the two pavilions is a large day-room, in which those patients who are able usually assemble.

Behind the centre is an exercising ground for convalescent patients; and between this and the two detached buildings, are the general exercising grounds, one for the male and the other for the female patients.

Except the portico, which is of stone, the whole edifice is of brickwork; and a critical eye may regret that the simplicity of so extended a line of building should have been destroyed by so many vertical divisions.

Hospital Milan.

The Hospital at Milan is considered as a structure uniting all the conveniences of such edifices in the highest itec- re.

degree, and its plan may, therefore, with propriety be introduced in this place. It consists of one great rectangle divided into three parts, nearly square and equal to each other. The central division is one vast area surrounded by buildings, before which, in the interior, are corridors on the lower and second stories, formed by arches supported on granite columns of different Orders. Each of the lateral divisions is again subdivided into four squares by two ranges of building crossing each other at right angles; within these buildings are the cells for the patients, disposed in two rows, leaving a broad corridor between them; and, at the intersection of the two corridors in each wing, is an altar; at these Divine Service is performed, which the patients can both see and hear without leaving their cells. Each of the courts in both wings of the Hospital is surrounded, in the interior, by two tiers of arcades forming corridors in front of the walls.

A grand vestibule, surrounded by columns disposed in the circumference of a circle, forms the front of the central division of the Hospital; at the opposite extremity of the same division is a large open portico wherein surgical operations are performed.

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The Naval Hospital, at Greenwich, which was erected on the site of the ancient Royal Palace, is a National Asylum for the reception of seamen who have grown old, or have been disabled, in the service of their Country. It consists of four quadrangular buildings disposed within the limits of one vast rectangle, the sides of which are nearly equal in length to 865 feet; and the buildings are separated by a broad area and a street, which cross each other at right angles. The principal front extends along the Southern bank of the Thames, and before it is a terrace, with steps in the centre to descend to the water.

The North-Western quadrangle was erected in the time of Charles II., from the designs of Webb, the son-in-law of Inigo Jones, and contains the apartments of the Governors, and the Council-room, besides sundry wards for the pensioners; the remaining buildings were begun by Sir Christopher Wren, about the year 1696, but they were finished by other Architects. The North-Eastern quadrangle is similar in style to the other, and having been finished in the reign of Queen Anne, it is called by the name of that Sovereign. The length of the Northern front of each of these quadrangles is 297 feet and the avenue between them is 270 feet broad; each of these fronts consists of three divisions, and in that of the centre is the entrance to the interior quadrangle; one of them is covered by a semicircular arch within the lower story, and the other by the general entablature of the building; each flank division is ornamented with four Corinthian columns supporting a pediment; on the right and left are coupled pilasters of the same Order; and above the whole front is a high Attic, crowned with a balustrade. The Southern façades of the same buildings are exactly similar to those on the North; both are of Portland stone, and rusticated. Each interior side of these buildings has its centre marked by four Corinthian columns supporting a pediment, and in the lowest story are three arched entrances to the quadrangle.

The South-Western and South-Eastern buildings bear respectively the names of William III. and of his consort Queen Mary, the original promoters of this noble institution. These are separated from each other by a square area, on a higher level than that next to the river, with a flight of steps on the Northern side extending the whole breadth of the area. At each of the two angles nearest to the general centre of the Hospital is a grand vestibule, adorned with coupled columns of the Doric Order, but having Attic bases and no triglyphs in the frize, and crowned with an elegant dome. Along the interior face of both the buildings is a double colonnade, 374 feet long and 20 feet high, consisting of coupled columns of the Order named above, and ornamenting a raised terrace. The lower stories of their Northern fronts are entirely occupied by the two dining halls, which are covered by groined ceilings supported on Tuscan columns; above these, in the Eastern building, is the Chapel, built in 1752, in the Grecian style, from the designs of Mr. Stuart, and in the Western building is the Grand Painted Hall: both Chapel and Hall are 106 feet long, 56 feet wide, and 50 feet high; the windows are very lofty, and are placed in semicircular-headed recesses.

Three of the buildings are of stone-work, but of that on the South-West, the two exterior faces, and those within its quadrangular area, are of brickwork. The last edifice was finished by Sir John Vanbrugh, about the year 1725, and contains some features which display the bad taste prevailing at that time: in the centre of one side of its interior quadrangle is a recess covered with an elliptical arch, and ornamented with two Ionic pilasters on each side; within the recess is an arched passage with small Corinthian columns standing on high rusticated pedestals, and supporting a pediment the cornices and tympanum of which are broken vertically into three faces; and, on the Western side of the same building, each of the flanks is crowned with a great segmental pediment.

Characteristics of Prisons.

The aspect of a Prison should be of a severe, and even gloomy character, in order that it may present a picture of the consequences which attend an infraction of the laws. But there are different degrees of crime, and the circumstances of Commercial Nations have rendered it necessary, in some cases, to treat as criminals those who are only unfortunate; hence it follows that prisons should be of various kinds, or, at least, that means should be afforded, in the same building, of keeping the different classes of prisoners distinct from each other.

If we consider a Prison as the abode of felons only, we may conclude that its Architecture should be of the most massive Order, its walls lofty and rusticated, and the faces of the stones rendered rough; the projections great, in order to cast broad shadows; the entrances arched with heavy voussoirs, and, where space can be afforded, it should be surrounded by a broad and deep ditch. The interior, however, should be convenient and salubrious, and, besides the cells, there should be large apartments where the inmates may occasionally meet and see their friends: when the Prison is intended as a place of correction for persons guilty of petty crimes, there must be places where such persons may prosecute their appointed labours, and debtors should have apartments in which they may exercise their callings for their own profit, or the benefit of their creditors

Newgate.

The Prison of Newgate, in London, which was constructed by Mr. Dance, and completed, in its present state, in 1782, forms three masses of building, together extending 297 feet in length from North to South; and the principal façade is in a rectilinear direction on the Western side. The plan of the middle division is a square of 115 feet; the Northern division is also a square of 91 feet; but the Southern is 91 feet long and 81 feet broad. In each of these squares the buildings are disposed about an open, rectangular court, which serves as a place of exercise for the prisoners; that in the centre for those who have not had their trial, the others are for the convicted male and female prisoners, respectively; but there are walls of separation in each, to form distinct places for those of different degrees of criminality. In the middle of the Western side is the Keeper's house, and behind it is a Chapel. For each sex there are two large general sleeping-rooms, a general day-room, an infirmary, and cells for separate confinement; a room in which the prisoners may see their friends; and at the North-Eastern angle of the ground, but quite distinct from the rest of the building, is a general room and separate cells for those who are condemned to die.

The Western or principal façade is rusticated from top to bottom with stones made rough on the exterior, which gives an appearance of rude strength; but the harmony of the Architecture is entirely destroyed by the Keeper's house, which has five tiers of windows in front, while only a few small apertures are apparent in the rest of the building. The Western parts of the Northern and Southern wings have each two projecting piers, with one niche containing a statue in a semicircular-headed recess, and an unbroken curtain between the piers. Between the Keeper's house and each wing is a small rectangular doorway at the foot of a large semicircular-headed recess; over the doorways are fetters sculptured in the wall, and the arched head of the recess is pierced for light. The whole front is 50 feet high.

The building presents an imposing and formidable appearance, and affords a good example of the effect that may be produced by mere magnitude almost without any decoration.

Penitentiary in Westminster.

A few years since a building was erected, by Mr. Hardwick, on Millbank, in Westminster, as a Penitentiary, or place for the reception of criminals who are to expiate their offences by undergoing a course of labour during a certain number of years, after which they are to be restored to Society. This building has been constructed according to a plan proposed by Mr. Bentham, for the purpose of affording a system of constant surveillance by the constituted officers. It consists of six pentagonal edifices, like bastions, disposed symmetrically on the sides of a hexagonal court, in the centre of which, on the ground-floor, is the apartment of the overseer; the whole is surrounded by a polygonal wall. The cells in which the prisoners perform their labours are placed at the gorges of the bastions, if they may be so called, and are open towards the great court, so that the overseer can command a view of all, from the windows in his apartment; above this apartment is the Chapel, to which there is a bridge of communication from the second story of each bastion, so that the prisoners can attend Divine Service without entering the court.

A plain, massive gateway forms an entrance to the building on the side next to the river, and another facing this, between the flanks of two bastions, leads to the hexagonal court. Along the river is a spacious terrace protected by a low wall, and a double flight of steps affords an ascent from the water The whole system of buildings seems well contrived for the accomplishment of its destination; but it may be thought that the rentrant angles between the bastions cause a great loss of space, and the site does not seem to have been well chosen, being so near the river and on a swampy soil.

Courts Justice.

Contiguous to a Prison should be the Court of Justice where the culprits are to be tried; and the most convenient form for a building appropriated to this purpose seems to be that which resembles the Theatres of the Ancients, that is to say, a semicircle, the tribunal of the Judge being placed on the chord of the arc, in the part corresponding to the proscenium. The general style of the edifice should be such as to inspire a sort of reverence nearly equal to that which is felt at the approach of one consecrated to Religion. The Court-house executed at Chester, by Mr. Harrison, is of the form above recommended; the seats of the persons connected with the proceedings rise from the floor in front of the tribunal towards the circumference of the circular part of the building; about them is a semicircular range of Ionic columns, and behind these is the gallery for the spectators. The Prison, which adjoins the Court at the chord of the circular part, is of a quadrangular form, and has in front a Greek Doric portico, the proportions of which are copied from the Propyleum at Athens.

The Court-house, at Warwick, is of a different form. This consists of a great rectangular Saloon, the principal façade of which, on the exterior of one of the long sides, is ornamented in the Palladian style of Architecture: on the opposite side of the Saloon are the Civil and Criminal Courts, one at each end, and on a higher level; these are open towards the Saloon, from which each is separated by a colonnade, and there are flights of long steps to ascend from the pavement of the Saloon to that of the Courts; between the Courts is the Jury-room, to which also there is an ascent by steps.

Bridges.

Bridges form some of the most important objects in Civil Architecture, by affording passages for the heaviest carriages across broad and rapid rivers, which by other means could not be passed but with difficulty and danger; and from the mass of masonry which, with the incumbent weight, is required to be suspended in the air, such a work as a Bridge demands the union of great scientific talent and practical skill in the Architect.

Situatio a bridg

The part of a river in which a bridge may be most conveniently formed is where it is nearly rectilinear, because the current of water being parallel to the banks, the bed is more uniform than in spots at which the river bends, and the piers, therefore, are more easily constructed. Also, the greatest force of the current being in this case in the middle, the vessels keep generally in that part; consequently, if the arches are not all equally broad, that which, on account of the passage of the greater number of vessels, is made the widest, will be in the centre, and the bridge may be symmetrically formed on each side. But when one side of a river is deeper than the other, and the greatest force of the current is near one of the banks, (which is the case when the river bends;) if, for any reason, a bridge should be constructed at that part, it will be proper to make the arch on the deeper side wider even than that of the centre, notwithstanding the want of symmetry thereby induced in the form of the bridge; convenience being attended to rather than beauty where necessity requires a sacrifice of one or the other. Bridges should be approached by long streets, on each side of the river; and, to facilitate the access, the parapet should diverge considerably at each extremity of the bridge.

Form road.

The most convenient form for the road over a bridge is, undoubtedly, a horizontal plane, like that of the Waterloo bridge, in London; but where the lowness of the ground on one or both sides of the river renders this impossible, or too expensive, the road must be of a convex form in the direction of its length, as is generally the case, in order that it may sooner meet the surface of the ground: this form is even considered more elegant than the horizontal plane, because, from an optical deception, the latter seems lower at the middle than at the extremities, when seen from the river in a direction perpendicular to its length.

The breadth of a bridge ought to be sufficient to allow at least two carriages to pass abreast, with a pavement on each side for foot passengers; and the road should be protected by a parapet and balustrade high enough to secure those who pass it from accidents.

Lon-bridge.

Under BRIDGE, in our *Miscellaneous Division*, we have described the principal edifices of that kind in Europe, it will therefore be necessary to mention here only the two of most recent construction in and near London. One of these is a magnificent edifice, now building, of granite, to replace the old London bridge; its length is to be 782 feet, its width 56 feet, and it is to consist of five elliptical arches, of which that in the centre has a span not less than 150 feet in extent, and a rise of 29 feet 6 inches; the others decrease gradually in breadth and height on each side, and the piers which support the central arch are 24 feet wide. It was begun, in 1825, by Mr. Rennie, a son of the engineer under whose superintendence the Waterloo bridge was executed; and it promises to be not inferior, in constructive merit, to that celebrated structure itself.

mer-h ge.

The other is a Suspension Bridge, 823 feet long, at Hammersmith, which exceeds, in the extent of road between the piers, the great bridge over the Menai. The chains, which are eight in number, and of wrought iron, pass, at 30 feet above the road, through apertures, in the upper parts of stone piers distant 400 feet from each other, and their extremities are attached to the abutment on each bank of the river; between these piers the chains assume, by their gravity, the form of catenarian curves, the lowest points of which touch the platform of the bridge over the middle of the river; and from the chains descend vertical rods which carry the timbers supporting the road. The piers rise from the bed of the river; below the bridge they are boldly rusticated, and, above it, each forms a triumphal arch extending across the road: at the angles are Tuscan pilasters standing on a general podium and supporting the entablature; the two sides of the arch spring from imposts which are continued through the pier, and the soffit is ornamented with panelling.

t Ar-cture.

The character of a Nation for good taste in the Arts depending, in some measure, upon the Architecture displayed in its cities, it is evident that the private buildings of which they are composed should be designed according to certain regulations, by which they may be adapted to their situations and be made to contribute to the magnificence of the whole.

Convenience seems to require that the streets should be rectilinear and intersect each other at right angles; but if this method was strictly adhered to, the horizontal lines of the buildings would, to a spectator looking along the street, appear to vanish in one point only, and thus the picture would want variety. Luckily, inequalities of ground almost always oppose themselves to this arrangement, and compel the builder to adopt some other which affords greater pleasure; the various angles at which the streets intersect each other, the interruption produced by great squares, and the judicious introduction of curvilinear forms of building, give to the scene in which they occur a beauty which would be in vain sought for in the appearance produced by two parallel lines of building.

Formerly, town-houses were constructed as independent buildings, and not the least attention was paid to equality or symmetry either in their heights or breadths, so that a street presented the confused appearance arising from two ranges of narrow and irregular fronts. But, at present, there seems to be an effort, wherever inequalities of ground do not prevent it, to give an air of grandeur and simplicity to the streets by uniting the fronts of several houses in one general design. This method was first practised in London, by Messrs. Adam, in the Adelphi and in Portland Place; but the good effect which these buildings might have produced is, unfortunately, injured by the manner in which they are ornamented. In front are pilasters ornamented with panels and sculptured foliage, seemingly in imitation of those which decorate the edifices of Palmyra, but harmonizing badly with the other features of the buildings to which they belong. And it is observed by Mr. Britton, speaking of the works of these artists, that, "in attempting to avoid the heaviness which characterises those of many of their predecessors, they have fallen into the opposite error; their façades are frittered into too many parts, and though the ornaments are occasionally tasteful, they are generally so applied as not only to miss their effect, but impart a trivial appearance to the building."

The principle introduced by Messrs. Adam has been adopted and practised on a vast scale in the buildings of Regent-Street and Regent's Park; but the designs are in a more elevated style, and embrace greater varieties of form. These ranges of buildings constitute what may be taken for a street of palaces, the individual characters of which are such as permit them, by their union, to form one grand system, while they have sufficient diversity to prevent the eye from being wearied, and to produce, together, a picturesque effect.

Modern Villas.

The Palladian Architecture was long employed in England for the general disposition and ornament of the villas, or country-residences, of persons of moderate rank or fortune. In these the principal story, like the *piano nobile* of the Italian mansions, was elevated on a basement, and the communications with the court in front and garden behind were by flights of steps. But it is observed by Mr. Papworth, that, in consequence of the change which has occurred in the habits and manners of the people of England within the last fifty years, this practice is abandoned; the principal apartments are now near the level of the ground, and are made to communicate with each other, so as, on occasion, to form one large apartment. The chambers are placed above these, and the offices are concealed from the view by small trees tastefully planted about them.

CHAPTER VIII.

General Principles of Architecture.

Ancient Architecture requires modification.

In investigating the principles which are to guide us in the execution of such Architectural works as shall fulfil the conditions which the present state of European Society requires, we may avail ourselves of every aid that we can derive from the practice of the Ancients. But our circumstances in respect to Politics, Religion, and Manners are different from those of the Greeks and

Romans, so also are our notions of domestic convenience; therefore it must not be expected that the maxims of building adopted by those People can apply without modification to our own constructions. There are, however, some points which must be common to all, and from these we may proceed to exhibit the grounds of the present practice of building.

Division of Architecture.

As edifices may possess properties which are merely essential to them, such as strength and convenience; or may unite to these, others which are intended to produce a pleasing effect upon the mind of a spectator, Architecture divides itself into two parts, *viz.* the constructive and the ornamental. The former is, in some measure, Mechanical, the latter, more particularly, may be considered as a Liberal Art. Both parts must be equally studied; for, besides paying due attention, in the design of an edifice, to the essential conditions of stability and convenience, it is necessary to render its external appearance suitable to the purpose for which it is intended.

Qualities of a building according to Vitruvius.

Vitruvius, (Book i. chap. iii.) speaking of public buildings, says they should unite in their construction strength, utility, and beauty. Their strength, he says, consists in having their foundations sunk to the solid earth, and in an unsparing choice of materials. Their utility consists in the apartments being properly distributed without obstruction to their use, exposed to the aspects which are convenient, and adapted to their respective purposes. Their beauty consists in the form of the work being agreeable and elegant, and the proportions of the members being correspondent to the rules of symmetry.

Modern buildings less material than the ancient.

With regard to the first of these points the practice of builders has undergone considerable change since the days of Vitruvius; the ancient edifices of all kinds were much more massive than the modern ones, and the Architects of earlier days seem to have been determined to err on the safe side. But now that frequent experiments, expressly made, have shown us, with tolerable accuracy, the strength of materials; and the rules of mechanics have taught us how to employ them in the way in which they are best able to bear the strains to which they may be exposed, we can dispense with a great quantity of material which would have been formerly employed, and which only served to encumber the edifice without adding any thing to its stability. The second part remains as in the days of Vitruvius, and admits of no change in its general expression; though the proper choice of aspects and the manner of adapting apartments to the purposes for which they are designed, vary with all the circumstances of climate and the habits of the People.

Supposed causes of the perception of Beauty.

The third point is more vague; no two persons can agree on what is elegant or agreeable; and, since the revival of the study of Science and Art in Europe, the cause of our perception of Beauty has been a subject of dispute both among Metaphysicians and Artists. Some persons consider our ideas of Beauty to depend upon certain qualities inherent in the object which, by a Law of our Nature, excite the perception as soon as they are apprehended; but that there cannot be such a thing as absolute Beauty will be readily admitted by those who consider that an object which appears beautiful to one person, appears the contrary to another: why this should be it is difficulty to determine, but probably it is on account of some prejudices, arising from early impressions, of which the mind is unconscious.

Others suppose the idea to depend upon the pleasure the mind experiences on contemplating an adaptation of means to an end in any subject; but, that this perception of Fitness should be always the cause of that of Beauty, is doubtful, because we often derive pleasure from the view of objects which do not necessarily involve in their being, an adaptation of means to an end; and when we do, we are often conscious of the perception of Beauty before we have taken time to notice that adaptation.

Our perceptions of Beauty in Architecture, according to Milizia, are founded on Nature and Utility. If it be inquired why a column appears beautiful in particular circumstances, he answers that a column is an imitation of a trunk of a tree employed to support an incumbent weight: but the trunk of a tree in such a case would have a certain figure and proportions, therefore, if the same figure and proportions be given to a column, we shall consider it beautiful, because the imitation of a natural object is always pleasing. He goes so far as to say, that if Nature had made trees equally slender with the stalks of corn, and, at the same time, strong enough to bear the greatest weights, the proportions of our columns would have been drawn from those objects, and we should still have considered them beautiful: but he seems here to overlook the circumstance, that great differences of magnitude and form in contiguous bodies are inconsistent with any of our notions of Beauty.

Lastly, it may be observed that intellectual associations form part of the pleasurable sensations we experience in contemplating certain objects; and this is particularly the case with works of Art. The Architecture and Sculpture of the Greeks and Romans possess an indescribable interest for us, because we always, in imagination, combine them with the circumstances of their Mythology and History, which usually occupy our thoughts at an age when the pleasing ideas they are calculated to excite make an indelible impression on our minds. And the Castlès of the Barons of ancient Chivalry, says Sir Joshua Reynolds, are sure to give delight on account of the veneration we feel for whatever brings to remembrance the manners and customs of our ancestors.

In fact, the mind is affected by objects from various circumstances, and, perhaps, the idea of Beauty may not arise from a single source. If absolute Beauty be not admitted, yet perception of fitness, intellectual associations, and various other causes, may, either wholly or in part, be concerned in the production of pleasurable sensation; and it will, probably, be for ever impossible to determine which of them is predominant in any particular case.

The inquiry into the origin of our perception of Beauty in general, however interesting it may be to the Metaphysician, need not be dwelt on any longer, and we may now direct our attention to the general conditions which are requisite in order to render a building conformable to the ideas of Beauty which we actually entertain.

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Three qualities are mentioned by Vitruvius as essential to Architectural composition, *viz.* Symmetry, Eurithmy, and Proportion; terms which have given great trouble to his commentators, and which, in fact, seem to be all comprehended under the general term Proportion. He defines Eurithmy to be the beautiful appearance of the members of an edifice, and shows that this is obtained by an adaptation of the heights of the members to their lengths and breadths, and by a correspondence of these to the symmetry of the whole. Symmetry also he defines to be an agreement of the members of a work, and the correspondence of the parts to the form of the whole; which is supposed to signify that some Proportion should subsist between the dimensions of any member and the dimensions of the whole building; but, as this definition falls partly into that which has been given of Eurithmy, it is customary to confine the signification of Symmetry to the corresponding distribution of like members on each side of a centre, as the members of the human body are similarly situated, on each side of a plane passing longitudinally through it. The word Eurithmy not being in use, perhaps it would be better to refer the magnitude and form of the members of an edifice to the term Proportion, and the distribution of them to the term Symmetry; agreeably to the general employment of those terms in ordinary Language.

The elements of architectonic Beauty which we find delivered by Vitruvius, are too general or too uncertain to allow us to consider them as the sources from whence we are to draw practical rules of construction; and we shall find it convenient, for this purpose, to make that Beauty depend upon, at least, four different principles, *viz.* Propriety, Proportion, Symmetry, and Unity.

riety in hitec-

The first principle is evidently conformed to, when the walls of a building have the proper degree of strength to enable them to support the roof, or but little more; when the size and distribution of the interior parts render them fit for the purposes to which they are to be applied; and when the degree of ornament given to the exterior and interior members accords with the importance of the edifice.

Propriety is evidently an essential quality in Architecture, and cannot be dispensed with where the stability of the edifice or the destination of any member is concerned; but it is observed by Sir William Chambers, that in objects merely ornamental, it would be unreasonable to sacrifice other qualities more efficacious, to Fitness alone. That Beauty and Fitness are not always compatible he shows by the example of the Corinthian capital, which represents a slight basket surrounded by leaves, an object certainly not fit to support an entablature, yet it has been admired for Ages, and will probably continue to be admired for Ages to come.

ortion.

Proportion is also an essential part of Beauty in Architecture; and it applies to the mass of the edifice as well as to the internal and external subdivisions. But what that Proportion is on which the perception of architectonic Beauty depends it is impossible to say. Some think it consists in the length, breadth, and height of a building or of any member being equal to three terms of a Geometrical or Harmonical progression; but the absurdity of this opinion is manifest from the consideration that the dimensions of an edifice may differ from those which are assigned by these proportions, without the eye, which is to be the judge of the Beauty of the building, being able to distinguish the difference. It is observed also, by Milizia, that the Beauty which is derived from Proportion in an edifice depends more directly upon the point of sight from which the edifice is seen than upon its absolute dimensions; since, according to the distance of any member, or to its height above the eye, its apparent magnitude, and even its form, is variable.

Experience then seems to be the only source from whence we are to obtain a knowledge of the relations which are capable of exciting perceptions of architectonic Beauty. "When," says Milizia, "we find that any number of parts, disposed in a particular manner, excites, in the generality of judicious spectators, pleasurable sensations, it is prudent, on the occurrence of similar circumstances, to follow exactly the same dimensions though there may be no discoverable relation between them." *Principi di Architettura Civile*, lib. ii.

Symmetry.

Again, Symmetry is also an essential part of Beauty; for that object can rarely excite agreeable sensations which is formed of dissimilar parts on each side of its centre. In the façade of a building, for example, there should be a doorway in the middle, and an equal number of windows, of like forms and dispositions, on either side: again, a bridge should have an equal number of arches on each side of that in the centre, and these should be either of equal magnitude or diminish by equal degrees on both sides. And it is easy to conceive, where absolute necessity does not compel the builder to depart from the principles of his Art, how much disgust would be excited by having a door placed nearer to one extremity of a façade than to another, or by having the principal arch of a bridge on one side of a river; or, finally, in an arcade, by having large and small arches intermingled together.

It is necessary, however, to observe that this Symmetry is only required where the whole object is seen from one point of sight; it would even be improper in an artist to bind himself to a uniformity of design in all the fronts of an edifice when those fronts are to be seen successively; such a repetition would be wearisome, and the spectator would lose that source of pleasurable sensation which arises from the variety exhibited in different fronts on the exterior, or in different apartments in the interior of any building.

Unity.

It is not sufficient that the parts of a building should be symmetrically disposed, there should also be some one part which forms the principal object, and to which all the others should be subordinate: this constitutes what is called Unity in an edifice, for it reduces all the parts under one system, and makes that an entire body which, otherwise, might be taken for a collection of independent members. The same principle requires that there should be but one Order of Architecture employed on the same story of any building; that, where Orders are placed above Orders, the most massive should be the lowest, and the others increase in lightness as they ascend; also that a cornice, since it expresses the termination of a building above, should not be formed between two stories. And it is essential to the unity of the design that no member, either of Architecture or Sculpture, should be introduced which is not consistent with the character of the edifice. Lastly, the different members should present themselves successively to the eye of the spectator in the order of their importance in the edifice; and the disposition should be such that the mind may form a general conception of the whole before it attends to the minute parts. These last, also, should be capable of exciting distinct ideas, and of conveying a notion of the uses for which they are designed.

Supposed standards of Perfection.

Milizia has advanced four different opinions concerning the standard of Perfection in Architecture. The first is, that it depends on popular judgment; but this is immediately dismissed, because it would be found subject to continual change, and a building would cease to be beautiful when its style ceased to be fashionable. The second is, that it depends on the conventions of

Architects; and this seems to be as ill-founded as the former; for not only the proportions assigned by the Moderns to the members of an Order differ from those which are found to exist in the monuments of antiquity, but each Architect, for the most part, has given a system, differing from those given by others both in the minute details and in many of the members upon which the peculiarities of the Orders of Architecture essentially depend. Vitruvius himself prescribes proportions to be employed in the construction of one kind of building which are different from those he recommends in another, though both are formed according to the same Order; and he approves in some places several things which in others he rejects. The third opinion is, that perfection should be sought in the remaining monuments of antiquity; but the diversity in their constructions is so great, that no general rule can be drawn from their dimensions, and the defects they exhibit are such that, if we were to consider them as invariable standards, there is hardly any violation of propriety which might not be justified by an appeal to some one or other of them.

Since, then, neither the authority of the masters in the Art, nor the existing examples, can be considered as infallible guides in the search after real Beauty in Architecture, Milizia is led to suppose that it is only by referring to the origin of the Art that certain constant principles can be elicited, which may be of service in the endeavour to produce such forms as will obtain general approbation; and, perhaps, it may be concluded that there are different styles of building, all equally capable of giving rise to the perception of Beauty, as far as it is founded upon the conformity of the works to the objects from whence they are derived.

General application of the principles of composition.

The following very general rules arise naturally from the principles before mentioned, under the heads of Propriety and Unity. The style of a building should be conformable to the ideas intended to be excited by its appearance; when we would produce perceptions of power, durability, and grandeur, the masses should be great, the subdivisions few, and those marked by transitions sudden and strongly contrasted; but, to inspire ideas of elegance, delicacy, and gaiety, the edifice should consist of many parts, differing by slow and regular gradations, and liberally ornamented. The same rule may be applied to the ornaments themselves, which, in proportion as they are more delicate, are to be formed by lines connected together less abruptly.

Perfect harmony should subsist between the whole edifice and the parts of which it is composed; for the same objects, viewed independently, may please, which, when combined, become ridiculous or disgusting; and even the same combination of parts which excites admiration when made in a work to the character of which they are conformable, may, in other circumstances, produce a contrary effect.

The course to be pursued by an Architect, in designing a public edifice, is to adapt his forms and proportions to the purpose for which the building is to be appropriated; to arrange the plans so that all requisite accommodations may be afforded; and to display the resources of his imagination in embellishing his work with such ornaments as shall be consistent with its destination. He should study examples of all the different styles which have hitherto prevailed, in order to produce an original work which shall unite the principal beauties of each; and he should infuse into his design the general character of the buildings proposed as models, without copying, servilely, any of their individual features.

CHAPTER IX.

Modern Domestic Architecture.

Best form for the pl of a dwel ing-house

A square or parallelogram is that which seems best adapted to the plan of an edifice intended as a dwelling, because it admits of great variety of internal division, and because the perspective of the figure is pleasing. Sir Henry Wotton, speaking on this subject, says the circle is a figure possessing many eminent properties in respect of durability, capacity, and beauty; the latter, inasmuch as it imitates the celestial orbs, and the form of the Universe, yet it is very unfit for private buildings, because it is the most expensive and causes the greatest loss of space from the curved form of the walls. Again he observes, that polygonal figures are more fit for Military than for Civil structures, and, no doubt, they partake of some of the inconveniences of circular forms; they may, however, be employed where the site is irregular, or where a system of buildings is to be disposed about a centre, for the purposes of inspection.

He decides finally for the rectangular form, the right angle affording greater strength than the oblique one; and he inclines to prefer the parallelogram, but recommends that its length should not exceed its breadth by above one-third, otherwise, he says, the beauty of the aspect will be diminished. Perhaps, however, the too frequent repetition of the rectilinear form in our edifices should be avoided, and particularly in country-houses; for, in these, the union of right lines with curves in the plan would create many pleasing varieties, and the inconvenience above-mentioned would be little felt.

General rules for division of houses.

The internal division of buildings, particularly dwelling-houses, may seem incapable of being reduced to rules on account of the infinite variety of situations, climates, and customs; and, perhaps, the only means of acquiring a knowledge of this subject will be to contemplate the plans of the most esteemed buildings which have already been executed. Nevertheless, as some general directions may be expected, the following are proposed; and they may perhaps teach the artist to avoid some improprieties in his designs, if they do not convey any positive information. Both the internal and external distribution of the parts should correspond with the character of the edifice; the divisions of a great edifice should themselves be great; of a small one, they should also be small; for it would evidently be highly improper to fill up a large building with small cells, or to have a large room in a little cottage. Again, it would be highly improper to fill an extensive façade with a great number of little windows, and equally so, to have great doorways and windows in a small house.

Externa dications the floo &c

When a building consists of two or more stories, the floors of those above the lowest should be indicated by the faciæ or entablatures over the corresponding Orders in the façade; and, in like manner, the vertical divisions of the façade should correspond with the places of the interior walls of the edifice. These correspondences cannot, however, in all cases, take place, because in the interior of a building there must be many divisions for domestic convenience which cannot be indicated in the front without impairing its majesty or beauty.

When an Order of Architecture is to be employed in

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Order.

a building, it is evident that that must be chosen which corresponds with the nature and use, and which may appear to be an integral and essential part of the edifice. The columns and their entablature, being the principal ornaments in Architecture, should predominate over all other ornaments in the same building, and they should have sufficient magnitude to make them appear to have a real use; therefore, in small buildings, the regular Orders should not be employed, because they appear unserviceable, and their members become indistinct from their smallness.

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Buildings of great importance and merit are frequently formed without columns or pilasters, which are generally considered as constituting the essence of an Order of Architecture; such buildings, however, admit of differences of style similar to those indicated by the Orders; for they may be either massive or light, or they may possess a character between both; and in those respects they may be compared, respectively, to the Tuscan or Doric, to the Corinthian, and to the Ionic Orders. The parts of which these simple buildings may be composed are basements, entablatures, and pediments, and they may be adorned with niches, balustrades, and various kinds of sculpture about the doorways and windows, according to the character of the edifice.

trances
dwell-
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The entrance to a mansion should be in the middle of the façade, in order that the communications may be made with equal facility to all the extremities of the building. To form two in the same front would produce embarrassment to a visitor, because he may be in doubt which of them leads to the principal apartments; but, in buildings of great extent, it is usual to have three entrances, one of which is in the centre and the others equally distant from it and from the extremities; in which case the first should be more lofty and adorned in a manner superior to the others.

tibule.

The vestibule should occupy the centre of the line of building, and serve as a general passage to the stairs and apartments on the ground-floor; its form may be rectangular, polygonal, or circular; and if the first, it may be divided into three parts by two rows of columns, which, with their decorations, should be of stone, because the place is much exposed to the air by the frequent opening of the door.

rtments.

In dwelling-houses of considerable magnitude two sorts of apartments are necessary; one, appropriated to the family in general, consists of rooms of moderate capacity, and at a distance from the places occupied by the servants; each should be accompanied by an ante-room, bed-chamber, and dressing-room; and in the same part of the building should be the common dining and withdrawing rooms. The state apartments, which form the other class, are destined for the reception of company; these should be very spacious, and enriched with the highest degree of ornament: all these apartments should communicate with each other, that, on public days, the whole magnificence of the house may be presented at once to the view.

ortions
oms.

The proportion between the three dimensions of rooms are, at the present day, nearly the same as those assigned by Palladio; all rectangular figures, from a square to one whose length is to its breadth in the ratio of 1½ to 1, may be employed for the plan; a greater disproportion ought not to be admitted except the room is intended for a Gallery. Sir William Chambers makes the height various, and dependent on the plan; if this is a square, the proportion between the height and breadth may be between the ratios of 1 to 1¼, and of 1 to 1⅓; if oblong, the height may be nearly equal to the breadth, except in Galleries, in which the ratio of the height to the breadth may be between 1⅓ to 1, and 1½ to 1.

In great mansions, where the rooms are of different sizes, he observes that the heights should also differ; the halls, saloons, &c., should be more elevated than the other apartments, and may, in some cases, occupy two stories; the withdrawing rooms may have horizontal ceilings resting upon the walls; but rooms of smaller size, if they have the same height as those, should have their ceilings coved, or connected with the walls by portions of cylinders, concave towards the interior, in order to diminish the apparent height; where this is not convenient, it is usual, above the smaller rooms, to place *mezzanine*, which are convenient for many purposes.

The state bed-rooms differ from the other state rooms only in being less enriched with ornament; they should look towards the South, and the bed should be opposite the windows; each should be accompanied by an ante-room, dressing-room, and other conveniences, and, when they are made of a rectangular form, they should differ but little from squares.

Galleries.

Galleries are a sort of apartments, in mansions of the first class, for the exhibition of works in Painting and Sculpture, which are placed about the interior faces of the walls; they receive their light from a lantern extending the whole length of the apartment, and raised high enough above the ceiling to prevent the direct rays of the sun from entering the eye of the spectator, after reflection from the Picture, which would otherwise be indistinctly seen. It may be observed here, that the most perfect view of a Picture is obtained when the rays of light fall upon it in different directions, so that many of them may enter the eye in a slightly divergent state from every point of it; and it is to multiply the directions of the incident rays that the glass of the lantern is usually ground with a rough surface. These apartments are generally made much greater in length than in width; that of the Louvre, at Paris, is 1458 feet long and only 80 feet wide.

Stairs.

The construction of a good flight of steps is considered as one of the most difficult works of the Architect. It should be immediately seen from the vestibule, and may be placed either directly opposite, or on one side of the wall facing the doorway, according to circumstances. In large buildings it is frequently double, the two branches meeting on each floor at a sort of vestibule, in which are the doors to the apartments; and besides the principal staircase there is generally another for the domestics of the family.

The best form for a flight of steps is that in which the several inclined planes are rectangular with a square platform at every turn; the curvilinear forms are very inconvenient, because, in addition to the fatigue of ascending, the person is continually turning, and one end of each step being narrower than the other, a great part of its length becomes useless, because the person, for safety, keeps always in the broader part.

In the generality of mansions each step should be long enough to permit two persons to ascend or descend abreast, and, therefore, that length cannot be less than 6 feet; in mansions of a superior order it may be as much as 12 feet. The breadth of the step should be about equal to the length of the foot, and experience shows that, in ascending, it is not convenient to elevate the foot more than 6 inches, nor less than 4 inches; from these data such dimensions may be chosen as will be consistent with other circumstances.

Convenience and security require that the staircase should be well lighted; for this purpose the light should come either from the head of the steps or from the roof of the building, and, on this account, that staircase is the best which may be seen from bottom to top.

Doorways. Doorways, serving for the passage of men, horses, and carriages, should be from eight to ten feet broad, and they must have arched heads, because their breadths hardly permit them to be covered in any other manner. The doorways which are to serve for vestibules may, sometimes, have arched tops, but, generally, they are made rectangular; those which form the entrances to apartments in a house should invariably be so, and of sufficient size to permit any man to pass: that is, their breadths may be from 3 feet to 3½ feet; and the heights of all should be equal to about double their breadths. The Ancients made their doorways narrower at top than at bottom, and we find the same form often adopted in modern buildings; but the only advantage of it seems to be that the doors have the property of shutting themselves. The height of the aperture of a doorway on the exterior of a building should not exceed three-fourths, nor be less than two-thirds of the space between the pavement or floor and the architrave of the Order, in order that there may be sufficient room for the ornaments, and that the wall above the doorway may not appear too naked. The upper extremities of the doorways and windows in the same story should be in one horizontal line.

The decorations of a doorway consist principally in the jambs or side-pillars, and the lintel or architrave; the breadths of these members should depend upon the Order of Architecture employed in the lowest story of the building, as if the jambs were pilasters the heights of which are equal to that of the aperture of the doorway, and their mouldings should correspond with the character of the edifice: over the architrave of the doorway, as if it was that of a complete Order, it is usual on the exterior of a building to place a frize and cornice; the latter supported by consoles which should be placed on the exterior of the jambs, in order that they may not interfere with the latter; and above the cornice is sometimes placed a pediment.

In great mansions the doors of state apartments are generally made from 4 feet to 6 feet wide, with folding-doors, which are thrown entirely open on days of entertainment. When several apartments communicate together, the doors should be as much as possible in a line, in order to permit a free circulation of air when all are opened, and to give a splendid view of the apartments, by exposing the whole suite of rooms. To increase the effect, there should be a window at each end of the suite, facing the doors of communication.

Windows. Windows occurring more often in an edifice than any other object, it is of importance to establish their dispositions and proportions with as much precision as possible. It would seem, at first, that the superficial content of all the apertures ought to be proportional to the magnitude of the apartment; but it will be found, on consideration, that no such proportion can be universal, for it must vary according to the climate, and the exposure to particular points of the horizon.

Mr. Morris, in his *Lectures on Architecture*, p. 109, proposes, for ordinary-sized rooms, the length, breadth, and height of which are in the ratio of the numbers 5, 4, and 3, respectively, that the square root of the continued product of the three dimensions should be taken for the superficial content of all the windows in the apartment. Now, if we suppose all the windows to be formed in one of the longest sides, it will follow from the above rule that the superficies of the windows will be equal to about one-half of that of the whole wall in which the windows are contained; in general, it is equal to little more than one-third.

The breadths of windows should be every-where the same in the same building, but considerable variations are permitted in the heights, which are generally made proportional to the heights of the apartments; and this inequality of size is not considered as detracting from the harmony of the external elevation, perhaps, because custom and a consciousness of convenience has reconciled us to it. In large mansions, where the second or principal story is more lofty than the others, the heights of the windows may be 2¼ times their breadths; in the ground-floor, the height may be double the breadth; and if there is a story above the principal one, the windows in it may be squares, or nearly so. It must also be observed, that the breadths of windows should never be greater than that of the piers between them, lest the wall should be too much weakened; nor should it be less than half the breadth of the piers, in order that the apartment may not be too much darkened; and the distances of the extreme windows from the angles of the building should be rather greater than the interval between two windows, to ensure the necessary strength of the wall in those places.

In the principal front of an edifice it is recommended to have an uneven number of windows, because, as the doorway is or should be in the middle of the front, a pier would otherwise stand over the doorway, which is not admissible. According to Sir William Chambers, the sill of the window should be about 3 feet from the floor, in order to permit a grown person to lean over it, and the top should rise to about 2 feet from the ceiling, in order to leave just room enough for the architrave of the window and the cornice of the room. Those called French windows descend to the level of the floor of the apartment, and are very convenient when they open upon a balcony or a garden.

If a window is contained within a semicircular-headed recess, the breadth of the former may be from ⅗ to 4/7 of that of the latter, and its upper horizontal *moulding* should be on a level with the impost of the arch or foot of the curvature; the bad effect produced by raising it above this level is but too apparent in many of the buildings in London; and if internal convenience will not permit the top of the window to be kept at the proper height, it would certainly be better to form no recess. The window may be crowned by a pediment within the recess; but, in this case, the pediment should be rectilinear, as one of a circular form, not being concentric with the head of the recess, would ill accord with it.

The same kind of mouldings may be given to the windows as to the doors; except when the former are near the roof, in which case there should be no ornament about them, because it might interfere with the entablature of the building. All the windows of any one story should be similarly embellished, but this is by no means necessary with those of different stories; on the contrary, a variety in this respect will be pleasing. The sides of windows are generally splayed or formed obliquely to the front, so that the apertures are larger within than without, in order to give more light and space to the interior of the apartment. When the windows or doors have horizontal heads, and the work is rusticated, the joints are usually made to converge downward to the vertex of an equilateral triangle, the base of which is the top of the aperture.

Palladian or Venetian windows are convenient for giving light to a Vestibule, Staircase, or long Gallery; and, for this purpose, they are still sometimes employed.

hes.

Niches are formed for the reception of statues, either on the exterior or interior faces of the walls of an edifice; their plan is generally semicircular, and the soffit a quadrant of a sphere. The proportion of the height of a niche to its breadth may be the same as that prescribed for a window, and both features may have the same decorations.

When the façade of a building is adorned with circular-headed niches, instead of windows, the former are generally enclosed within a rectangle, having the same proportions and embellishments as the latter; the bottom of each niche should coincide with the base of the rectangle; but a certain interval should be left between the sides and top of the niche and those of the rectangular enclosure.

The interior of the niche should be always plain, as any ornament would partly destroy the effect intended to be produced by the statue; and the latter should be contained within the plane of the general face of the wall.

-places.

In Northern climates, the fire-place of an apartment is an important object, and its disposition and form require some precautions, in order that it may afford the greatest possible degree of comfort.

The best situation seems to be in the middle of that wall which is opposite the windows, because that side is warmer than the others; and, as it has been recommended to place the door in one of the walls at right angles to this, the persons seated about the fire will not be so much annoyed by the cold air introduced on opening the door, as they would be if the fire-place were in any other situation; nor, by this disposition, is the smoke so likely to descend into the room on suddenly shutting the door. The fire-place should never be between the windows, because the recess and funnel would weaken the wall on that side of the house, and the opposite wall of the room would be wanting in ornament.

The aperture of the fire-place should bear some proportion to the size of the room; in ordinary rooms it is a perfect square, in small ones its height is greater than its breadth, and in large ones, generally, the contrary. In the smallest apartments, the width of the aperture is never less than 3 feet or 3½ feet, but, in others, it may be from 5 feet to 5½ feet; and when the room is of such magnitude that one fire-place is not sufficient to give warmth to every part, it is customary to construct in it two, directly opposite to each other.

On the Continent, and in some old English houses, the fire-place projects into the room, but this produces a mean effect; when, however, from the thinness of the wall it is unavoidable, the parts on each side should be occupied by closets; and when several fire-places are situated one above another in different stories, the flues should be parallel to each other, but without any communication, because the smoke from one flue would enter the other by the aperture, and descend into the room. The tops of chimneys must be raised above the roof of the house, and should be concealed, if possible, by the balustrade.

The decorations of fire-places are similar to those of doorways or windows; the jambs consist either of faciæ plain or sculptured, or they are ornamented with columns, pilasters, or Caryatides; above is an architrave, which is frequently surmounted by a frize and cornice, and the upper surface of the latter forms a shelf.

Manner of ornamenting the interior of a building.

In buildings of great magnificence, the interior is frequently decorated with the Orders of Architecture, as well as the exterior; and propriety teaches us that the interior Order ought to be the same as the exterior one on the same story, though the Ancients did not always attend to this principle. The interior faces of the walls are usually adorned with half-columns or pilasters, between which, in the lowest story, are niches; frequently, a portion of the apartment is separated from the rest by a screen of columns, and the upper part of the wall is terminated by an entablature on which rest the beams of the ceiling. An objection has been made to the employment of a cornice in an interior entablature, because its projection, which was intended to protect the lower part of the wall from the rain falling on the roof, is not required where no rain can fall; nevertheless, custom seems to have authorized this deviation from propriety, and the practice has, in some cases, a plausible reason in its favour, since it may be supposed to present a broader bearing for the timbers of the ceiling than would be afforded by the tops of the walls alone: the same reason, however, cannot be given for the introduction of triglyphs and guttæ, as ornaments in such a situation.

When the pavement in one part of the interior of a building is lower than in another, the columns, in the lower part, may stand on pedestals, in order to bring their bases on the same level as those on the higher pavement; in other circumstances, pedestals are unnecessary in the interior, and they are even inconvenient, since they take up more space than can, generally, be afforded. Sir William Chambers considers the plinths of columns in apartments to be also unnecessary, because the pavement will protect the columns from the dampness of the ground, to do which was the original intention of the plinth. Columns cannot with propriety be placed on inclined planes, as along the sides of a flight of steps, because the abaci and plinths, being horizontal members, can only be adapted to such situations by placing a block above the one and under the other with oblique surfaces to suit the contiguous planes, and this gives the columns an appearance of great instability.

In ordinary apartments, the faces of the walls are usually ornamented to represent those of an entire building, with what propriety it may be difficult to say. The lower part has the appearance of a continued podium standing on a plinth, and terminated by a cornice, or, as it is called, a surbase moulding, at about 3 feet from the floor; and the face of the dado is generally ornamented with square panels: the wall above the dado is also ornamented with panels, the breadth of which is equal to that of the panels below, but their height is much greater, since they extend nearly to the ceiling; a cornice is formed at the junction of the walls with the ceiling, so that even in such apartments the idea of an Order of Architecture is preserved, the styles or vertical portions between the panels being supposed to represent columns or pilasters.

Ceilings.

The manner of ornamenting the ceilings of rooms at the present time does not differ much from that practised by the Romans. In lofty apartments, the ceiling is composed of beams framed into each other, so as to form square or polygonal compartments; the sides of the beams are generally adorned with mouldings, and the soffits with guilloches or fretwork; and the surfaces of the compartments with paintings or bas-reliefs, representing figures, foliage, festoons, and the like. When the rooms are low, the ornaments may be in painting or stucco, and the mouldings must have small relief, but they should be well executed, on account of their being near the eye of the spectator.

In mansions of a superior character, the ceilings are sometimes coved; the horizontal part, which, generally, then, forms a large panel, being joined to the walls by portions of elliptical or circular cylinders; the curved part rises from a little above the cornice, and terminates on the margin of the panel.

The soffits of arches are frequently enriched with guilloches or frets, when narrow; but, when broad, with panels, the surfaces of which are adorned with various devices.

CHAPTER X.

Proportions and Distribution of the ornamental Features of Edifices.

Proportions of the columns.

The Orders of Architecture have suffered little modification since the revival of the Roman style, and, from a comparison of many of the best examples executed within the present century, we may consider the heights of columns, when expressed in terms of their diameters, to be fixed as follows. In the Tuscan Order, seven and a half diameters; in the Doric Order, eight; in the Ionic Order, nine; and, in the Corinthian and Composite Orders, ten diameters. In the first three Orders, the heights of the capitals may be each equal to half a diameter, and, in the last two, to an entire diameter; and, except in the Doric Order, which has no base, we may consider the heights of the bases to be equal to half a diameter.

Diminution of the shaft.

The difference of the upper and lower diameters of a column is now usually made equal to one-sixth of the latter; but, if we express the difference of the semi-diameters in terms of the length of the shaft, we shall have for the diminutions in the different Orders $\frac{1}{78}$, $\frac{1}{90}$, $\frac{1}{96}$, $\frac{1}{102}$, $\frac{1}{102}$, respectively; from which it is evident that, in the more delicate Orders, the inclination of the side of the shaft to the axis is less than in the more massive, and the diminutions are inversely proportional to the heights: but, by the laws of Optics, the apparent diminutions of the columns bear some ratio to the elevation of their summits above the eye; consequently, the greater apparent diminution of the higher columns is, partly, at least, corrected by a smaller real diminution. The celebrated Mathematician, La Grange, had the curiosity to ascertain, on analytical principles, whether the practice of enlarging the soffits of the columns at about one-third of their height, according to the supposed precepts of Vitruvius, had a tendency to increase their capabilities of resisting compression in the direction of their length; but his investigations terminated in the proof that a cylinder is the figure which, with an equal quantity of material, presents the greatest resistance; consequently, the enlargement of the columns, if it could be supposed to give elegance to their appearance, adds nothing to their strength.

Proportion of the entablature.

The entablature being borne by the columns, its mass should evidently bear some proportion to theirs, and this is accomplished by making the height of the former depend upon the diameter of the column; for then, if the heights of the columns in all the Orders were made equal, the heights of the entablatures would differ in the same proportion as the diameters, and the more slender columns would have the lower entablatures; consequently, the burthen they have to sustain would be nearly proportional to their strength. This rule of propriety is, evidently, not observed when the height of the entablature is made to depend on the height of the column in all the Orders, as prescribed by Palladio; for, by such means, the burthen bears a higher ratio to the magnitude of its support in the more slender, than in the more massive Orders: as far, however, as appearance is concerned, this evil is, in part, removed; for the richer Orders, having their entablatures broken into a greater number of parts, the apparent heaviness of these members is thereby lessened, and they approximate to the delicacy which should characterise them in those Orders.

Architects of the present day assign to the entablatures in the different Orders heights which vary from 1¾ diameters to 2½ diameters; and the heights of the architrave, frize, and cornice are, generally, in the proportion of 3, 3 and 4, respectively; except in the Doric Order, in which the terms 2, 3 and 3, more commonly express the relative heights of those members.

Improbability that a new Order can be invented.

It has been gravely questioned whether it is possible to invent a new Order of Architecture; and if we consider the attempts that have been made at various times to produce one, and the number of Ages during which the principal Orders already existing have enjoyed universal approbation, we may feel disposed to answer in the negative; perhaps, therefore, an artist would be hardly justified in spending time in an effort so unlikely to be attended with success. No one can deny that it may be possible to give new proportions and new ornaments to the members, but no one is willing to admit that any or all of these will constitute a new Order; such must not only differ from others in the above respects, but it must also possess beauty, and produce in the mind of the spectator a perception of novelty. Even those which are called the Tuscan and the Composite Orders do not universally meet with a favourable reception, and many artists hesitate to consider them entitled to an existence independent of the others. Perhaps the only thing that can be done is to seek in Nature for new ornaments which may be applied to the parts of an Order already in use; the bases, capitals, and entablatures may by such means receive improvement; the shaft seems to admit of none, because its greatest merit consists in the smoothness of its surface, or in the very simple modification produced by channelling.

Gener rules app

The beauty of a composition depends upon the arrangement of its parts and mouldings, in which this general rule should be followed, *viz.* that the straight and curved lines which their sections form should succeed each other alternately, the eye being then able to enjoy the effect of ornament without confusion. In each member there should be one governing feature, to which the others should be subservient; this should generally be some principal moulding which, being caught by the eye, affords a good indication of the use of the whole member, and thus assists the spectator in apprehending the form of the work; and the subordinate members should be such as appear to be intended either to support, strengthen, or protect the principal one: thus, in the cornice, the corona is the principal member; the modillons and dentels are ornaments connected with it; the ovolo supports them; and the cymatium crowns them. The curvilinear mouldings may, in general, be ornamented with sculpture, but the square members, being commonly employed to give distinctness by separating the others, should be left plain, in order that they may more effectually perform their office.

isposition
the orna-
ents.

The greater ornaments should be disposed with a certain regularity, and, in conformity with their intention; thus the middle of a mutule and triglyph, of a modillon and a dentel, should be placed in a vertical plane passing through the axis of each column; exception being made in favour of the Grecian practice, which, in the Doric Order, required the triglyphs at the extremities of the frize to be placed close to the angles, and thus destroyed the regularity of the ornaments, and even of the intercolumniations. This circumstance, however, is only permitted on account of the predilection which the mind feels in favour of the works of that interesting people; for any such liberty in a style of modern invention would be highly reprobated.

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g its front.

Anciently, the basement of a building was a sort of platform elevated a few feet above the level of the ground, and serving as a general plinth or pedestal to the whole building. Round the Temples or porticos of the Greeks and Romans the sides of the basement were, generally, as we have seen, cut in the form of steps, to give access to any part of the colonnade above; and, when those sides were formed by vertical walls, they were without ornament. But the name of basement is now given to the lowest story of an edifice in which there are more than one; and this story being of considerable importance, it becomes necessary to give it a certain degree of embellishment. When any of the apartments for the family are in the basement, this story should be as high as two-thirds of the whole Order immediately above; but when it contains only offices, it may have but half that height. It should never be higher than the Order above, because the latter is always the principal part of the edifice.

The face of the basement, and, it may be added, of the whole building, is frequently distinguished by rustic work; which, originally, consisted in leaving the exterior face of the masonry rough, probably to save expense and time; but sometimes now it is, by way of ornament, purposely executed in imitation of a material so left. Stonework marked in this manner conveys an idea of strength, and it seems most properly to be applied about the gates of Fortresses, the entrances of Prisons, and, in fact, on every building the aspect of which should be rude and strong: it may also be employed on walls rising from a river, or from the sea-coast, as it then gives them the appearance of having been cut from the natural rock.

A work is also said to be rusticated when the faces of the stones are smooth, but the vertical and horizontal joints are marked by channels; and the term is likewise employed when only the stones at the angles of the buildings are so marked; in these cases, the length of each stone between two vertical joints should be three times the height or distance between the horizontal joints. The profiles of the channels are sometimes rectangular, and then the breadth and depth may be each equal to one-eighth or one-tenth of the height of the course; but in the more massive works they are triangular, the rentrant angle being a right angle, and the breadth of the channel from one-fourth to one-third of the height of the course. Occasionally, the vertical channels are omitted, and this kind of work is called French rustication; but it seems less proper than the other, because it takes away the character of masonry, and causes the building to appear as if made of planks.

An arcade is frequently formed in the basement story of an edifice, in which case, instead of an entablature, the story is crowned by a projecting facia, either plain or ornamented with simple mouldings; the height of the facia should be about equal to that of the horizontal courses of masonry, the imposts of the arches may be of the same height and form, and the plinth may be rather higher.

Attic story.

The upper part of an edifice is generally terminated by what is called an Attic Order, consisting of a wall, the height of which is about one-third of that of the Order above which it is placed. The Attic wall is either continuous, with a simple base and entablature resembling those of a pedestal, or it is interrupted at intervals by small pilasters which are sometimes ornamented with bas-reliefs; the dado between the pilasters is also frequently embellished with sculpture or inscriptions. The breadth of the Attic pilaster should be the same as the upper diameter of the column or pilaster below, and its projection should be one-fourth of its breadth. In the interior of a building, when vaults spring from the walls, there is usually employed what is called a false Attic; that is, a sort of continuous pedestal, which is intended to elevate the springing of the arch above the entablature of the walls.

Employment of
Orders in
the front of
a building.

The use of the Orders of Architecture is, undoubtedly, to embellish the exterior of an edifice; and Nature indicates that, when the building consists of but one story, only one Order should be employed; for either the columns of one Order must be higher than those of another, and then the entablature of the shorter columns will be interrupted by the shafts of the others; or, if the heights of the columns of the different Orders are equal, one will appear more slender than the other, and, consequently, unfit to bear the weight which is adapted to the strength of the other; this misapplication of the Orders is, however, very common, and occurs in some of the most magnificent buildings of Europe. But when the building consists of several stories, it is reasonable that a different Order should be employed in each story; and there is no impropriety in employing one or more of the Orders of Architecture in the superstructure of a building when the basement has an arcade in front, since a range of arches has been found to have sufficient strength to support any edifice which it may be convenient to place over it.

A colonnade with its entablature indicating the construction of a whole edifice in itself, it is evident that, where two or more are placed in altitude, there is conveyed a perception of as many edifices piled one on another. Now there is no impropriety in this, when the magnitude of the edifice seems to require it, but it is evident that the design should be formed with regard to the unity of the whole system.

Application of the Orders in tiers.

It has been observed, (in part ii. chap. vii.,) that the strongest Order should be placed lowest in the edifice, and that the others should diminish in strength progressively upward; it will follow, therefore, that the Tuscan or Doric may be employed on the ground story, the Ionic above this, and the Corinthian or Composite may crown the whole. If a heavy Order, like the Doric, were placed above a light one, such as the Ionic, it is evident that there would be produced, if not a real, at least an apparent weakness of construction, and both are equally improper. The repetition of the same Order in two stories of the same building should be avoided, because it would produce an uniformity which is not pleasing; and, since an abrupt transition from one extreme to another is equally disagreeable, it is evident that an intermediate Order should not be omitted.

There is also an impropriety in giving a cornice to the entablatures of the lower Orders in a building composed of several; first, because their projection will conceal the lower parts of the columns or apertures above, from the view of a spectator below, and thus alter their apparent proportions; and, secondly, because a cornice indicating the crowning or upper member of an edifice, should be reserved for the superior Order alone. Architraves and frizes will suffice to form the entablatures of the other Orders, and mark the situations of the intermediate floors.

Lastly, when the columns are detached from the wall, it is an obvious principle that the axes of all should be placed in one vertical line, the stability of the building absolutely requiring that whatever supports a member should be itself supported. When the columns are attached to the face of the wall, an adherence to this rule is of less importance, because the upper members of the edifice are less supported by the columns than by the walls below; in this case, it will be sufficient to make the axes of the columns appear to correspond when viewed in front; and if the upper part of the building is made to retire from the lower, so as to assume a form approaching to that of a pyramid, the columns must retire also, as is the case with those in the upper Order of the Theatre of Marcellus; but the amount of this recession should not be considerable, and perhaps it should be only so much that the front of the plinth of the upper column may be vertically over the face of the top of the shaft below it.

Proportions of columns in tiers.

According to Scamozzi, the lower diameter of an upper column should be equal to the upper diameter of the column below it, as if the whole system of columns standing in a vertical line was one long column cut horizontally at the different floors of the building. This rule, which is derived from that given in the Vth Book of Vitruvius, seems well founded in Nature; and, if the heights of the several columns be determined by the lower diameters of the shafts according to the rule for each Order respectively, and, at the same time, the diminution of each shaft, instead of being in a constant ratio to the lower diameter, were made variable, increasing with the delicacy of the Order, by making it equal to $\frac{1}{8}$, $\frac{1}{7}$, or $\frac{1}{6}$ of the lower diameter in the Doric, Ionic, and Corinthian Orders respectively, as proposed by Milizia, *Principi di Architettura*, p. 149, it will be found that those inconveniences mentioned (part ii. chap. vii.) are in some measure obviated. The breadths of the intercolumniations in the different Orders remain nearly proportional to the heights of the Orders, and the triglyphs and modillons admit of a regular distribution; but, on account of the increase of the intercolumniations in the upper Orders, it will be hardly convenient to have more than two Orders in the same front.

The columns of the upper Orders may be placed on continuous pedestals, or on plinths, high enough to permit the bases of the columns to be seen from below over the projecting members of the entablature. These plinths are preferable to isolated pedestals, because the latter will appear too heavy; but when two tiers of arches are employed, the height and breadth of the apertures above being greater than those below, in order that the upper piers may not appear clumsy, it may be necessary to give pedestals to the columns which adorn the piers, so that those columns may have sufficient height; and, in this case, the cornices of the pedestals should not be continued on the faces of the piers, because the sides of the latter ought to appear uninterrupted from top to bottom.

Intercolumniations.

The different species of intercolumniations employed in the works of the Ancients have been already stated; it remains, therefore, only to explain the practice now generally followed in disposing the columns. When columns or pilasters are near, or are attached to the faces of walls, it becomes necessary that the intervals should be regulated by the breadth of the windows, doors, or niches, the exteriors of the jambs of which should be nearly in vertical planes passing through the sides of the plinths of the columns; at least those jambs should not be concealed by the columns, since the wall would then appear to want solidity. In peristyles and porticos the intercolumniations are either diastyle or eustyle; except when the Doric Order is employed, and then, Sir William Chambers prefers the ditriglyph intercolumniation, or that which admits two triglyphs over the interval. In a portico, the middle interval should be broader than the others, in order the better to distinguish the centre of the façade; but when the columns are coupled this rule may be dispensed with, because the variety would then become too great, and create confusion in the appearance.

Employment of coupled columns.

There are many cases in modern Architecture in which coupled columns or pilasters may be employed to advantage: first, when a line of building is pierced by windows or niches at distances from each other too great to permit the wall to be sufficiently covered by a single column; again, when a front is occupied by single columns, the piers at the extremities being generally wider than those between the windows may require coupled columns, or pilasters, or a coupled column and pilaster, to make their degree of ornament correspond with that of the other piers; and, lastly, when an Order of columns is placed above an arcade, and the width of the piers between the arches is considerable, those columns may be coupled, to procure a breadth of ornament corresponding with that of the pier below. In general, the pairs of columns are situated in a vertical plane coincident with the architrave, but in the interiors of vestibules or courts, we frequently find them disposed in planes at right angles to the entablature they support, in order to unite strength with lightness.

The plinths of the columns in each pair may be brought quite in contact with each other, but it is necessary to avoid making the mouldings of the bases, or the ornaments of the capitals, intersect each other, as this would create a confused appearance, and spoil the effect; still less should it be permitted to make one shaft unite with the other, as is done in the Gothic, and some of the Roman works. The chief difficulty which arises from coupling the columns in the direction of the length of the building is the irregularity it produces in the disposition of the triglyphs and modillons, which can hardly be made to correspond with the centres of the intercolumniations and with the axes of the columns. An approximation, however, must be made to this by altering the intervals of those ornaments in such a way that their deviation from the general rules may be as little perceptible as possible; and the method of doing it is fully detailed by Sir William Chambers in his *Treatise on Architecture.*

asters.

Pilasters are still frequently employed in buildings where columns would be too expensive or inconvenient: they serve the same purposes as columns, and, in modern works, they have, generally, the same proportions and mouldings.

Scamozzi recommends that the shaft should project from the face of the wall so much as one-quarter of its breadth, in order to give it a bold appearance; and that, when it is of the Corinthian Order, the leaves on the flanks may be cut exactly in the middle. But if the imposts of arches, or the cornices of windows or doors, occur between the pilasters, the projections of the latter should be greater than those of the former, in order that the face of the pilaster may not appear to be broken by them.

The reasons which are given for diminishing columns may serve also to justify the diminution of pilasters; *viz.* the pleasure produced by that form, and by the good proportion of its capital, which, without the diminution, would appear too heavy; but when the faces of the pilasters are to be fluted it will not be convenient to diminish them, because the oblique directions of the channels on a plane face would produce a disagreeable effect. The capitals of Ionic pilasters are to be formed with oblique volutes, and agreeably to the rules given for the Ionic columns, in order to permit the ovolo to pass between the interior curl of the volute and the top of the shaft.

Pilasters are no longer placed at the extremities of the front of a portico, because the difference of their apparent thickness, when viewed in front and diagonally, renders it impossible to make their proportions harmonize with those of the columns: but, at the extremities of walls, or at the quoins of buildings, they are sometimes more convenient than columns, because the angle of the entablature projecting beyond the face of the column seems to hang in the air unsupported, when seen obliquely. And when a portico is formed by columns in advance of a wall, it is usual to place pilasters behind them against the face of the latter, in order to serve as a support for the entablature on the flanks; this, however, should be dispensed with when the depth of the portico is small, because of the confusion arising from the mouldings of the columns and pilasters being blended together.

als.

The employment of pedestals by the Ancients has been already mentioned, and we purpose, now, only to show in what cases they are admissible in modern Architecture. When a portico is elevated upon a basement, and a balustrade, serving as a fence, is required for the safety of the persons within, the columns may be raised on pedestals, because the base and cornice of the balustrade can be made to unite with those of the pedestal, which they could not do with the shafts of the columns; and, in this case, the breadth of the dado may be about equal to that of the plinth of the column above it. Palladio makes the height of the pedestal equal to one-fourth of that of the column, and this seems to be the proportion generally followed in the present practice. Pedestals are again admissible when the pavement within or about a building is not on the same level, in order to raise the bases of all the columns to an equal height; and in our Churches, Theatres, and Courts of Justice, pedestals are also necessary to allow the bases of the columns to be seen above the pews, or the heads of the persons assembled.

The objections to pedestals are, that they take from the columns that air of majesty which should accompany them; they diminish the intercolumniation; the angles of their cornices are liable to be destroyed; and, when they are attached to the faces of buildings, their mouldings do not accord with those on the lower parts of the walls.

Employment of arcades.

The wish to avoid the expense of columns for the support of an incumbent mass of building, and to procure larger apertures than could be obtained by them, led, no doubt, to the employment of arches. In ancient buildings, the intrados or inferior curve line of the arch was always semicircular, and the sides of the voussoirs were made to tend to its centre: at present, since, in many cases, very wide spaces are to be covered, and it is inconvenient to give great height to the crown of the arch, the semicircular form often becomes inadmissible, and one approaching to an ellipse or cycloid is adopted; on the other hand, where the required height is greater than half the span or chord of the arch, a parabolical form has been employed. The construction of arches, and the conditions requisite to procure an equilibration of the materials composing them, are given under Bridge, in our *Miscellaneous Division;* we, therefore, confine ourselves here to their application, as ornamental features, in the façades of buildings.

Proportions of arches and piers.

To obtain a pleasing effect, when arches are so employed, Architects recommend that the height of the aperture from the pavement to the crown should be about double its breadth, and that the breadths of the piers should vary with the Order employed in the building; according as the Order is Doric, Ionic, or Corinthian, those breadths may be respectively two-thirds, one-half, and one-third of the breadth of the aperture, and when no Order is employed, the breadths of both may be equal. The thickness of the piers may be about one-third of their breadth.

In edifices of great magnitude, the arch-stones appear in their simple state; and if the façade of the building is rusticated, their joints are also marked by grooves; but in highly-ornamented works the archivolt or exterior face of the arch is enriched by mouldings, and the key-stone, or voussoir at the vertex, is generally sculptured. The line of voussoirs sometimes rises from the top of the pier without any thing to mark its commencement, and, in other cases, an impost, either plain or adorned with mouldings, serves to distinguish the top of the pier from the foot of the arch; the breadth of the archivolt and impost may each be equal to about one-eighth of the breadth of the aperture.

Application of columns or pilasters to arcades.

Columns or pilasters may be employed to ornament the faces of walls in which arches are formed, and, in this case, they should have the appearance of supporting a horizontal entablature above the crown of the arch. The columns should project before the walls as much as one-half, or even three-quarters of a diameter, and the breadth of the pier on each side should, at least, be equal to half a diameter, that the supports of the arch may appear to have sufficient solidity. There should also be some distance between the top of the archivolt and the architrave of the Order, for the wall has an appearance of weakness if the latter rests immediately on the crown of the arch.

The adaptation of the Doric Order of columns to an arcade is a work of some difficulty, on account of the widths of the arches not corresponding to the exact space which any number of triglyphs should occupy; the means proposed have been, first, to diminish the breadths of the triglyphs and metopes; secondly, to increase the heights of the columns by raising them on plinths; or lastly, to omit the triglyphs entirely.

Pediments.

Pediments are the triangular spaces formed at the extremities of a building between the horizontal cornice and the inclining sides of the roof. it is evident, therefore, that they can only be used with propriety at the summit of a building; but, because the windows and doors are surrounded by mouldings which project beyond the face of the wall, it is customary, also, when they are not near the roof, to form small pediments over those apertures, in order to throw off the rain; and, for the sake of variety, when several windows are placed in a row, the pediments are alternately in the form of a triangle or of a segment of a circle. The taste for variety might, perhaps, be correctly indulged this far; but the insatiable desire of novelty has led men to adopt forms which are utterly irreconcilable with any notion of propriety; the first example of which is, perhaps, the interrupted pediment in the ruins of Balbec. In later times, the sides of these broken pediments have been made in the forms of right lines, arcs of circles, or curves of contrary flexure; and Sir William Chambers observes, that they have been formed of two half-pediments with the summits outward. Every attempt to refine upon that form which corresponds to the original intention of the pediment, destroys its effect by causing it to appear useless; for this reason, it is highly improper to omit the horizontal entablature, or even to break it vertically, as is sometimes done.

Proportions of pediments.

Buildings of a curvilinear form on the plan do not admit of a pediment, because the roof can have no such termination; neither can a pediment be introduced in the interior of a building because there is, there, no rain to be thrown off; and it is, evidently, equally absurd to form, on the exterior, one pediment above another, since it would convey the idea of a roof placed over a roof.

Architects differ greatly on the subject of the proportions of pediments, some considering that the inclining sides of all pediments, great or small, should form the same angle of inclination with the horizontal cornice; but Sir William Chambers observes, that one with a short base should be proportionally higher than one the base of which is long, otherwise the tympanum will afford no plain repose for the eye; and, on this principle, he proposes that the height of the apex of the fillet under the cymatium should vary from one-fifth to one-fourth of the base, according to the extent of the latter: it is evident, however, that this proportion can only apply to buildings in which the Roman character is preserved.

When the pediment covers the whole front, there is a difficulty in connecting the inclined cymatium of the pediment with the horizontal one on the flank of the building; because, if both have the same profile, the former is higher in the vertical direction than the latter. To remedy this fault, some persons break the inclined cymatium at the foot, and give the lower part a horizontal direction, in order that it may coincide with the flank cymatium; but this appears a deformity, and Sir William Chambers recommends making them coincide by diminishing the projection of the latter.

Ornam in pe- ments.

If we adhere to the prototype of a building we should say, that as there can be no joists nor planks in the roof above the frize, when the building is covered by a pediment, there ought to be no modillons nor dentels in the horizontal cornice of that member; such ornaments, however, are constantly employed in that situation. Parallel courses of longitudinal timbers above the rafters are also represented by modillons on the sloping sides of the pediment, and are made to stand vertically over the modillons of the horizontal cornice. The face of the tympanum is in a plane coinciding with that of the frize, and, in the manner of the Ancients, it is still adorned with sculpture. At each foot, and at the vertex of the pediment, are usually placed acroteria, or pedestals for statues or other ornaments, the height of which should be regulated by the possibility of seeing those ornaments from the proper point of sight on the ground.

Balustr

Balusters were, originally, a sort of dwarf-columns employed to enclose a space within the interior of some building, or to surround an elevated platform which was intended for a promenade; but, subsequently, they were also used as ornaments on the tops of buildings. Their general form is that which has some resemblance to a pear, with a simple astragal above and below the swell; each has a square plinth resting upon a continued podium, and, at top, is an abacus supporting the general coping of the balustrade. Sometimes, however, each baluster resembles two of the above kind joined base to base, and these, being lighter than the others, are employed in the more enriched works. In most cases they should be about 3 feet or 3½ feet high, so that a man may lean on them; but, when they are placed on the tops of buildings for ornament, or on bridges for the prevention of accidents, they should be higher.

When balusters are applied to a row of arches, they should be placed within the apertures of the latter, in order that they may not interfere with the faces of the piers; the cornice must be on a level with the tops of the pedestals supporting the columns which are attached to the piers, and both that and the base should have the same profile as the corresponding members of the pedestals. On inclined planes, the abaci and plinths of the balusters should have the form of frusta of wedges, that they may be adapted to the plane; but the mouldings should always be horizontal.

Emplo ment o Order circul irregu buildi

The Grecian and Roman Orders of Architecture seem ill adapted to buildings of a curvilinear or polygonal form; for the lateral faces of the abaci and plinths, which should be at right angles to the others, become oblique to the wall; or, if those faces are made perpendicular to the latter, the plans of the members become trapezoids, and, therefore, do not harmonize with the circular mouldings of the bases and capitals. And when columns are disposed in the circumferences of two concentric circles, they not only produce a confused appearance when seen from any point but the centre, but a great embarrassment arises from the intercolumniations in one circle being too great or too small, when those in the other are made conformably to the rule; it has been attempted to palliate this last evil by giving a small increase to the distances of the columns in the exterior circle, and contracting those of the other columns as much as that excess.

When a column is placed at an oblique angle either on the exterior or interior of a building, a certain irregularity is produced in the base and capital; and, to avoid this, it has been proposed to place there a pilaster broken longitudinally in the middle, and forming a face on each side, the breadth of which has the regular proportion to the height; others recommend that there should be no column or pilaster exactly at the angle, and that the last one on each face should be brought as near as possible to it, by which means the want of solidity there will be scarcely sensible.

es.

After the return to the Architecture of Greece and Rome, the prejudice in favour of lofty Churches, which had prevailed in the Gothic times, continued in force; and as this could not be obtained where the roof is supported by columns, the heights of which are limited by the proportions they should bear to their diameters, it was necessary to raise an edifice above the general roof; and thus the dome, mounted on a high cylindrical wall and strengthened or ornamented by columns, may be considered as replacing the Gothic tower over the intersection of the nave and transept. This construction does not involve any great deviation from good principles; but when a low dome is formed over a building which has already a pediment-roof, as is generally the case, it is liable to some objection, because the pediment represents the finish of the building, and the dome becomes superfluous.

In order that a considerable portion of the exterior of a dome may be seen from the ground, and thus produce a good effect, it should be of a spheroidal form with the longest axis in a vertical position; but in the interior this is not necessary, and the deep concavity of the spheroid would even take off from the beauty of the feature by giving it too much the appearance of an inverted well, therefore a hemispherical form is, here, more proper: and it was to obtain both external elevation and internal elegance, that the triple domes of the French Churches, and that of St. Paul's, in London, were constructed. With respect to the double, and nearly concentric domes at Florence and Rome, they have been made to unite lightness with strength; to prevent the humidity of the external air from affecting the paintings on the concave surfaces of the inner ones, and to permit a covered communication from the base to the lantern.

CHAPTER XI.

Materials employed in Buildings.

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It has been commonly observed that the edifices of the Ancients far exceeded those of the Moderns in durability, and the observation has some appearance of truth if the comparison is made between the Grecian or Roman Temples and the dwelling-houses of the inhabitants of modern Europe; but its justice may be doubted in almost every other case. It must be admitted that the Ancients spared neither labour nor skill to construct edifices which should triumph over every accident, and the walls and columns of some of them have stood more than two thousand years, in spite of the injuries of climate and the efforts of Man to destroy them; but it cannot be denied that many of our Churches, Bridges, and other public works possess the quality of stability in an eminent degree, and promise to attain an age equal to that of the edifices of antiquity. The dwelling-houses of the Ancients seem to have had no better pretensions to durability than our own; for, except those which have been preserved under the volcanic matters which overwhelmed them, they have all long since disappeared. And it may be alleged in excuse for the slender construction of modern houses, that their frequent renewal affords opportunities for improvement in taste and execution, which would have been wanting if the works had been originally made more durable.

The Gothic Cathedrals of our ancestors seem, at first sight, far inferior in stability to the Heathen Temples of the Ancients; but this apparent weakness results only from their forms; the area of the horizontal section of a clustered pillar often exceeds that of the most massive of the Grecian columns, though it has a much lighter appearance; there is consequently a probability that it will have a more than equal durability. The roofs and ornaments of our Cathedrals may speedily fail, if not repaired, but the roofs of the ancient Temples have also disappeared; and even the fine climate of the South of Europe has not entirely spared the sculpture which adorned those buildings.

An Architect should be acquainted with the qualities and stress of materials.

The first essential, however, in the security of an edifice is the choice of such materials for its construction as are best capable of resisting the stress and strain to which they are liable; and a knowledge of the nature and properties of bodies, and their capabilities of resisting extension or supporting compression in every direction, is indispensable to every one who aspires to the name of an Architect. This may be added to the other qualities enumerated by Vitruvius.

Since all materials do not possess the same resisting power, and those of the same quality are not equally good for all sorts of work; it is evident that one circumstance to be attended to is the placing materials in such situations that the weaker may be subject to a less degree of force than the stronger. In an edifice too, some parts, as the foundations and lowest parts of walls, have to sustain pressures in vertical directions; others, like the piers of arches and domes, have to resist pressures laterally; some bodies, like the tie-beams in roofs, are subject to the strain of extension; and, lastly, others, such as vaults, roofs, and ornaments, are themselves supported. It is of importance, therefore, to ascertain the species of force to which the part of an edifice will be subject, in order that opposing forces may be applied to it in the proper directions; and the degree of stress or strain must then be determined that the resistance may be adequate to it.

In a general Essay, like the present, it will be evidently improper to enter into a full explanation of the nature of minerals, woods, and metals; such knowledge is not absolutely necessary to an Architect, and we, therefore, confine ourselves almost wholly to an enumeration of those materials which are principally employed in building. The equilibrium of the parts of an edifice is, also, too extensive to be introduced in this place.

Marble.

Marble is a calcareous material forming simple mountain rock; it is of various colours, as white, yellow, grey, green, and red; its structure is always granular, and its uses for statuary and ornamental Architecture are well known. The purest kind is that obtained from the Island of Paros, in the Archipelago, but much use is made of that from Carrara, in the Apennines. Marble, also, of various qualities, abounds in Scotland and in many parts of the Continent of Europe.

Granite.

For those rude works which are to endure for Ages, as bridges, prisons, and the like, granite is the material which should be employed, but its great hardness, and the consequent expense of working it, render it inapplicable to buildings which are embellished with an abundance of sculpture. An inferior sort of granite is brought from Cornwall, but that which is chiefly employed in this Country is obtained from Scotland, and the Aberdeen granite seems to be particularly valued for its hardness, beauty of colour, and capability of taking a fine polish. Some granites have the quality of resisting the action of air for thousands of years, but there are others which are speedily decomposed by it, and reduced to gravel and sand; and this difference of quality is sometimes observed in contiguous portions of the rock.

Portland stone.

That which is called free-stone is chiefly calcareous, but it is often compounded of calcareous, silicious, and argillaceous materials, and it has obtained its name from the facility with which it may be wrought. The best is that which comes from the Island of Portland, which has the quality of resisting corrosion from exposure to the air. It has been in great request in England since Sir Christopher Wren employed it in the numerous edifices which he raised after the fire of London, and it is used in almost every department of the building Art.

Purbeck stone.

The Island of Purbeck furnishes a species of stone, composed of marine remains cemented by calcareous spar. It is harder than Portland-stone, and consequently less easily wrought; being inferior to granite, it is less frequently employed, and chiefly for paving the foot-paths of streets.

Bath stone.

A similar kind of free-stone is that obtained from Bath; it is much used for ornamental work, being soft when obtained from the quarry, but becoming harder when it has been for some time exposed to the air.

Fire-stone.

Fire-stone is a soft kind of free-stone, obtained largely from Ryegate, in Surrey; it has the property of resisting the action of fire, and, therefore, is very fit for the interior of fire-places, but it is not employed for any other purpose.

In choosing stone for building, that is to be preferred which is best capable of resisting compression, which does not splinter by the action of frost or fire, and is not liable to decomposition by the air. Granite and marbles should be employed as soon as possible after extraction from the quarry, because then they may be cut with less difficulty; but the softer stones should be tried by exposure to the air for a considerable time before they are used, in order that their quality may be ascertained, and that they may be perfectly consolidated.

Stone in the quarry is disposed in strata parallel or oblique to the horizon; and it has been observed, that, when employed in buildings, it should be placed in the same situation with respect to the horizon that it occupied in the quarry, being then best capable of resisting compression.

Bricks.

Bricks have been employed in building from the earliest times, either burned or unburned; and the generality of their use is, no doubt, to be ascribed to the facility with which they are formed. Experience only can show what kind of clay makes the best bricks; it should be very adhesive; stones and mud should be carefully taken from it; it should be well worked, with little water, and mixed with ashes or sand. The best bricks give an acute sound when struck; they should not change colour when immersed in water, and they should suffer no alteration after being exposed during winter to the frost. The heavier ones should be employed for foundations, and the harder and lighter for works above ground.

Tiles.

Tiles are manufactured in a way similar to bricks, but of a better material, and their forms are various. Those called plane tiles are rectangular, 10½ inches long, 6¼ inches broad, and ⅝ inch thick; and, when placed on the roof of a building, they are held in their places by pegs which pass through two holes in the tiles and between the laths. Ridge tiles are nearly hemicylindrical, 13 inches long, and 11 inches diameter, and they are placed along the horizontal and oblique ridges of roofs. A coarse kind called pan-tiles, the surface of which is a curve of contrary flexure, is employed for the covering of sheds and other roofs of small elevation. Plain tiles of two different sizes are employed for paving, and the larger of the two is 1 foot square, and 1½ inch thick.

Slates.

Slate is a species of stone of a blue or purple colour, which is split in laminæ of small thickness and of various sizes, from 1 foot square to 3½ feet long and 2½ feet wide. When employed for the cover of a roof, they are placed over a bed of flat boards, and are kept in their places by copper nails passing through holes drilled for the purpose. Next to copper and lead, they form the most durable cover for roofs; but, in this situation, they should be of a kind which will not readily imbibe water, because the water rots the boards under them. Slates are also employed for paving.

Lime, mortar, and sand.

Lime is formed from limestone or chalk, by exposing those materials to a red-heat in kilns, when the carbonic acid is drawn off and the lime remains pure. Upon being wetted it readily falls to powder; this is passed through a sieve or screen of wire, and the finer part being mixed with sand and water, constitutes the mortar employed in building, which becomes hard by exposure to the air. When the mortar is made sufficiently fluid to penetrate the materials which it is to unite together, it is called *grout*. The sand, which is a crystallization of vitrifiable earth in small particles, should be obtained from natural beds in the earth, or from the bed of a river; it must be free from clay or mud, and the particles should be bounded by angular surfaces. When works are to be under water, a different sort is required, and that called *Parker's cement* seems to answer the purpose best, as it hardens quickly both in air and water; it is obtained by burning a sort of limestone found in the Isle of Sheppey.

Oak.

Oak is used in building for beams and joists, for door and window-frames, and, when cut in planks, for stairs and lining the sides of rooms; and on account of its strength and durability, it is preferable to every other kind of timber; but its most important application is in ship building. The name of *wainscot* is given to a sort of oak imported from Holland; this is softer than common oak, but it is less liable to warp and split. Another kind of oak, called *clapboard*, is imported from Norway; but both of these kinds are less used in England now than formerly. In the choice of oak trees, those the trunks of which are most even should be preferred, as swellings in the trunk are symptoms of decay; when cut down, the bark is taken off, and the tree laid for some time in water, to season, before it is squared and cut up.

Three kinds of fir wood are chiefly used in building; one, called the yellow fir, which comes from Scotland, Norway, and the shores of the Baltic; the second, called spruce fir, is a native of Denmark and Norway, but it also grows in the Highlands of Scotland; and the third is the American pine. The best firs which are brought to England are those of Riga, Memel, and Dantzic; and the deals, or wood of the fir-tree cut into planks, are imported from Norway, Dantzic, and St. Petersburg. This kind of timber is used to a great extent for partitions, for lining the sides of rooms, for doors, windows, and the like.

ard oods.

Other timbers occasionally used in England are mahogany, a wood from the West Indies, which takes a fine polish, and is chiefly employed for furniture, but, sometimes, for doors, rails, and the like. Walnut, which is used for cabinet-work and gun-stocks. Chestnut, a wood much resembling oak, and employed for turnery ware and for vessels to hold water. Ash, which is tough and strong, but decays when exposed to the air. Elm and beech, which may be employed for piles if they remain constantly under water. Sundry other English woods might be enumerated as applicable to many useful purposes, and their growth, on this account, is deserving of encouragement.

on.

Cast-iron is now much in use for building, particularly for roofs of houses, bridges, railings, and the like; but, in works of magnitude, the changes it undergoes from variations in the temperature of the air are so considerable as to be very detrimental to the stability of the edifice, and render great precautions necessary to prevent accidents: it is also much subject to decomposition by the air, and must be preserved by varnish or paint.

Wrought-iron is employed for bars, hinges, bolts, screws, and many other purposes, in which its tenacity renders it most useful; but it is evident that its good qualities must depend upon its being well forged.

pper.

Copper is employed in the formation of cramps for stonework, because it resists the action of air better than iron. When alloyed with a quantity of zinc equal to one-third of its weight, it forms brass, which is used for the handles of doors, locks, drawers, &c.: if the quantity of zinc is only from one-fifth to one-tenth of the copper, the mixture forms bronze or bell-metal, which is used for statues, bells, cannon, &c. Copper in the form of sheets is a very durable covering for the roofs of buildings, to which purpose it is frequently applied.

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Lead, when reduced to the form of sheets, is, also, much used as a covering for buildings, and as a lining for cisterns, and is bent or cast in the form of pipes for the conveyance of water. It is not much corroded by the action of the air, and it is not at all altered by pure water, but if the water contains any saline particles, a crust is formed on the surface of the lead exposed to it. The sheet-lead is either cast at once of the required thickness, or, after casting, reduced by pressure between rollers; and the latter kind, which is called milled lead, is now generally preferred. For a more detailed account of the materials employed in building, see Gwilt's *Rudiments of Architecture.*

CHAPTER XII.

Part IV.

Practice of Building.

Precautions in building on a rock,

The foundations of a building should be laid upon a bed of great solidity, and if the natural ground is not sufficiently firm, artificial means must be employed to make it so. If the building is to be raised on a rock, it will be necessary to ascertain whether there are any cavities below the surface which may render it incapable of supporting the weight of the walls; if so, piers must be built in the cavities, and arches turned between them to increase its strength; and, before the foundations are laid, the surface of the rock must be rendered rough, if not so naturally, in order that the mortar may insinuate itself, and unite the rock with the masonry placed upon it.

on gravel,

Gravel affords a support nearly equal to rock, and it may be built upon with safety. If cellars, vaults, or other subterranean apartments are to be formed, the whole interior below ground must be excavated; but, if not, trenches only are dug where the walls, both interior and exterior, are to be built; the bottoms of these trenches are to be in one horizontal plane, unless the surface of the ground be considerably inclined to the horizon, in which case they must be formed in portions, with horizontal beds like steps, one lower than another.

Vitruvius and Palladio recommend that the breadth of the foundation at bottom should be equal to double its breadth at the level of the ground; in modern practice the difference between the two is not so great, but it is evident that this must depend on the height of the edifice and the quality of the ground. The depth of the foundation is also variable, but, generally, one-sixth of the height of the edifice.

In good ground, sleepers are laid two feet asunder across the trench; the intervals are filled with dry stone, and, over these, is a floor of planks in the direction of the trench. Upon this the first courses of stone are laid, without mortar, because the lime will corrode the wood; but the next courses, whether of stone or brick, should be disposed with regularity and well bonded together. Whatever precautions are used with the foundations of the outer walls, the same should be used with those of the interior walls, that they may all settle equably; and, for the same reason, the foundations should all be executed at the same time.

on clay,

In building upon clay, the best method is to level it and lay down a horizontal grating of timber rather broader than the intended foundation; the intervals may then be filled with bricks, mortar, and the like, over which boards may be placed and nailed to the grating. The walls are, afterward, to be raised above the boarding as before.

on sand, or on a marsh,

When a substratum consists of sand, common earth, or marsh, it will be necessary to drive piles vertically into it till they reach the solid ground; their tops are then cut off in a horizontal plane, and on them is laid a grating of timber as before, above which the edifice is raised. Where the substratum is marshy, or otherwise defective, and a great weight is to be supported on columns, the following method has been adopted. A hole was dug at the place where the column was to stand, and, into it, a quantity of gravel was thrown to the depth of three feet; on this was laid a block of solid stone, which served to support a pedestal of brickwork, the upper surface of which was on the level of the ground, and the column was placed above the whole.

The foundation walls at the angles of buildings should be thicker than in other parts, and additional precautions should there be taken to render the bearing secure, because a failure would be attended with more serious consequences at the angles than elsewhere. An interesting account of the means taken by Sir Christopher Wren to secure one of the angles of St. Paul's Cathedral is given in the *Parentalia*.

in water.

Foundations may be laid in water by throwing into it stones and cement, in successive beds, with a slope on each side, the base of which is equal to its height, till the mass rises above the surface of the water; and, in this manner, the Breakwater, at Plymouth, was formed. Frequently, in building the piers of bridges, caissons or coffers of wood are moored over the place where the pier is to stand; the building is begun within the caisson, and the weight of the material causes the latter to sink on the spot prepared for it by levelling the bed of the river. When the work has been raised above the level of the water, the sides of the caisson are removed and the piers remain. But the most secure way is to enclose a certain part of the river within a coffer-dam formed by double-sheet-piling: the space between the rows of piling is filled up with bricks or some other material, and the whole rendered water-tight; then, the water being thrown from the interior by engines, the work may be effected as on dry land.

General rules for building above the foundation.

After the foundations have been established, the walls should be raised above them, in vertical positions, by which alone they can have the required stability; their thickness, however, should diminish upward, both from motives of economy and to lessen the pressure on the parts below. No part of the wall should have a false bearing; a pier, for example, should never be placed over an aperture, and, moreover, vertically under the windows or other apertures; inverted arches should be formed below the ground, in order that the pressure of the walls on the ground immediately under them may be diminished by throwing some of it on the intermediate parts.

The lower courses of masonry in a stone wall should consist of large, rectangular blocks, each of which should, if possible, extend quite through the thickness of the wall; or, if stones of sufficient length cannot be obtained, they should be placed so that their long and short sides should be presented alternately to the front; and the vertical line of junction of every two stones in one course should fall over the middle of a stone in the next lower course. This is called *breaking joint*, and it gives a better union to the whole system of masonry in the building

Manner of laying the bricks.

That which is known by the name of *English bond*, and was formerly much used in this Country, consists in disposing the bricks so that those in the alternate courses have their longest sides parallel, and, in the intermediate ones, perpendicular to the front of the wall; all the bricks have their broadest faces placed horizontally, and by these dispositions it was intended to bind the materials well together in the directions of the length, breadth, and height of the building. But the method now employed, which is called *Flemish bond*, consists in placing them in horizontal courses, with the largest surface downwards as before; but in each course, on both faces of the wall, the bricks have their lengths alternately coincident with and perpendicular to the face, and are so arranged that in one face, the *headers*, or those the ends of which are presented to the front, are opposed in the other face to the *stretchers*, or those the long sides of which are in front; the intervals are filled with whole or portions of bricks according to circumstances. A similar arrangement takes place in the different courses, and care is taken to break joint in all cases. It is evident that the method which affords the greatest number of bricks, the lengths of which are in the direction of the length of the wall, will form the best bond longitudinally; and that which affords the greatest number, the lengths of which coincide with the thickness of the wall, will form the best bond in that direction: and it may easily be shown that the Flemish bond has the advantage in the former case, and the English bond in the latter.

Strength o walls.

The thickness of brick walls is made to depend chiefly upon their height; but, where they have only to sustain their own weight vertically, less will suffice than when they have to support arches or roofs which may exert a lateral thrust. The angles at which two walls unite should be well strengthened, and, in rabble work, those parts should be formed of squared stone in order to give beauty and firmness to the building

When the walls are high, the thickness upward is usually diminished at intervals by offsets like steps; in houses, this is usually done on the interior face only, but it would be better to have it done both on the interior and exterior faces, and, to avoid any inelegance of appearance, in the latter situation it may be concealed by ornaments.

Bond tim bers.

Beams of timber are placed longitudinally, at intervals, either in the centre of the wall or close to its interior surface; the former situation seems the most proper for increasing the tenacity of the brickwork, but the latter is more convenient when the apartments are to be lined with wood. In the other case, wooden plugs must be inserted in the walls, in proper places, that to these the wainscotting may be nailed.

The construction of simple arches having been sufficiently described under Bridge, in our *Miscellaneous Division*, it will be only necessary here to add a short account of some other kinds of vaults which are occasionally employed in edifices, and chiefly in parts below the level of the ground.

Groined vaults.

Groined vaults may be imagined to be produced by the hemicylindrical vaults covering two galleries which cross each other at right angles; and, if both are of equal magnitude, the curved sides of the vaults will form, by their intersections, four elliptical ridges, which converge to a point over the centre of the square made where the galleries meet each other.

It is evident that in the ordinary way of building this kind of vault, it is supported entirely by the intersections of the courses of masonry in the lateral vaults, and that these intersections form ribs which rest on the four angles of the walls or piers; the dimensions of the ribs are limited by the thickness of those vaults, which cannot be considerable, and their strength is diminished by the oblique manner in which the stones or bricks are cut at the salient angles of the ribs. Hence this species of vault seems to be the weakest of all coverings, and ought, of course, to be employed only where there is a necessity of having both direct and lateral communications through the interior of a building.

Improv groined vaultin

To procure additional strength in this kind of vaulting, Mr. Tappen proposes to cut off the salient angles of the piers in vertical planes parallel to the diagonals of the vault, and to raise from the tops of the piers two diagonal ribs equal in breadth to the oblique face thus formed on the pier, and of any convenient thickness; the lateral arches which, in this construction, are smaller than those of the common groined vault, are united with, and borne by the ribs, and the latter, instead of being the weakest part of the vault, may be now as strong as the rest. The extremities of the arches between the ribs are made to meet the sides of the latter, at four inches from their faces, by which means the oblique cutting of the bricks at the angles is avoided.

As the area of a transverse section of these diagonal ribs may be easily made two, or even three times as great as that of the intersection of the lateral arches of the common groined vault; it is evident that the strength of the vault proposed by Mr. Tappen may be made to exceed that of the other in the same proportion. We may add that the new method presents greater facility of construction than the old, and it is probable that the vault is not inferior, in power of supporting weights, to that the form of which is hemicylindrical.

Where an extensive area is covered with a ceiling of stone or brickwork, a system of groined arches becomes absolutely necessary; these must be supported on piers, and in order to afford more room and take off the corners, which are liable to be destroyed by accidents, the piers should be of an octangular form: vast ranges of arcades thus formed and supported are to be seen in the subterranean parts of the warehouses at the London Docks.

loister- aults.

A different kind of groined vault has been formed by four portions of cylinders rising from a square base, joined together in four ridges salient towards the exterior, and meeting at the apex of the vault: this, which is called a cloister-vault, was employed in Gothic and Saracenic Architecture; and the dome of the Cathedral at Florence is formed on the same principle, but the cylindrical portions are raised on the sides of an octagonal base.

rumpet- aults.

When a superstructure is to be raised over the rentrant angle between two walls which meet each other, a vault in the form of a portion of a cone is constructed for its support; the vertex is placed in the line of intersection, and the semicircular base of the half-cone is in a vertical plane passing through the outward extremities of the walls. These are called trumpet-vaults, and they were formerly constructed for the support of buildings over the rentrant angles formed between the faces of a bridge and its projecting piers. Vaults of this kind, but of an elliptical form, are much more appropriately employed in supporting the landing-places on the winding stairs, at some of the warehouses before mentioned.

bility of es.

Domes are most conveniently constructed on circular bases, for then their vertical pressure is equally supported at every point, and the voussoirs in each horizontal course are all of the same form and equal magnitude. A dome, having all its parts in perfect equilibrium, might be constructed by giving such a form to its vertical section, that the vertical weight of a stone in any one horizontal course, combined with the oblique pressure of all above, may produce a force acting in the direction of the next course below; but a dome of this form would be one of the weakest, as well as the least elegant, whereas, if the curve line formed by the vertical section were made to fall between the axis and the curve of equilibration, the pressure of the upper horizontal courses would tend to force the lower courses towards the axis; this taking place equally round all the circumference of any horizontal course, the effect would be to keep all the stones in that course more firmly together than if such pressure had not existed. All domes hitherto constructed have this character, but the cone between the two domes at the Cathedral of St. Paul possesses it in a greater degree than any, the forms of which are convex towards the exterior; they exert, however, considerable thrust horizontally round the base, and, hence, it has been found necessary to strengthen them by iron hoops, as we have stated, in speaking of the domes of St. Peter's and St. Paul's.

When a dome is to be raised over a space enclosed by four walls at right angles to each other, the rentrant angles of the walls are filled up by pendentives, as formerly described, the surfaces of which coincide with that of a spherical zone inscribed between the walls; the tops of these pendentives form a horizontal circle, upon which either the dome itself, or the cylindrical wall which is to support it, is erected.

Domes of timber are generally constructed on the same principle as trussed roofs, and the curved ribs are disposed in vertical planes passing through the axis. The boldest piece of carpentry known was the old dome of the Halle du Bled, at Paris, the form of which was hemispherical and its diameter 200 feet; each rib was formed of planks 9 feet long, 13 inches thick, and 3 inches broad, placed three together in the direction of their breadth, and connected horizontally at different distances by purlines and iron straps, which formed hoops to the whole. This roof was destroyed by fire, and it has been since replaced by a dome of iron, of which each rib is composed of frames disposed in a vertical plane, and every two connected together by simple bars; the whole is covered with sheet copper.

CHAPTER XIII.

Modern Architecture in the East.

Little account of the Architecture of the East will be required, it is not probable that Asiatic buildings will afford many subjects for imitation in the Western World; partly from the difference of climate, but chiefly from the differences in the manners and customs of the people; and, perhaps, copies of them will never be executed in Europe, except to gratify the fancies of amateurs. The taste which can be pleased with an imitation, in plaster, of the massive edifices of Egypt, may lead some one to erect a cottage resembling a Turkish Mosque, or a Chinese Pagoda.

Mosque of Sultan Achmet.

From the time that the Empire of the Saracens was at its height, to this day, a style of Architecture, similar to that which we find in the Mosque at Cordova, and in the Alhamra, has prevailed in the edifices of the Mohammedans. These are generally covered by cupolas, and at the angles are slender minarets or turrets, from the tops of which, when the building is appropriated to Religious purposes, the Imaums call the Faithful to their devotions. The Mosque erected at Constantinople, by Sultan Achmet, in 1610, may, perhaps, be considered as the best specimen of the Mohammedan Religious edifices of comparatively recent date; in its plan, it bears considerable resemblance to the Basilican Churches of Constantine, and its roof is evidently copied from that of Sancta Sophia.

The whole building is formed on a rectangular plan, the longest side of which is 270 feet, its shortest 155 feet, and the height of the containing walls 37 feet. It is divided into two equal squares, of which the first, within the entrance, is a court open to the sky, in the centre, but surrounded by a covered corridor, with arcades towards the interior, and in the roof of the corridor on each side of the quadrangle are eight small, hemispherical domes. The second quadrangle constitutes the body of the building; about its centre are four piers, disposed at the angles of a square of 60 feet, and supporting semicircular arches with pendentives; upon the tops of these is a cylindrical wall perforated by semicircular-headed apertures, for the admission of light; and above the wall is the great dome, the exterior surface of which has the figure of a bell, and whose height, from the pavement of the building to its vertex, is 82 feet. Between the four piers, are formed segmental recesses, which are covered by half-domes, the crowns of which are on a level with the base of the tambour under the central dome. In each of the angles formed by the four recesses is raised a slender, octagonal turret to the height of 70 feet; and at each of the four angles of the parallelogram enclosing the whole Mosque, and in the middle of each of the long faces, is raised a minaret 120 feet high; it stands upon a square pedestal, and is divided by two small platforms into three cylindrical portions, of different diameters, and above the uppermost of these is a spire which crowns the whole. The pavement of the Mosque is elevated 8 feet above the ground, and there is an ascent by steps to the entrance doorway, which is crowned by an arch of contrary flexure.

An imposing effect is produced in the interior of buildings of this kind by the tiers of vaults, which rise above each other within one great concave surface, and are covered with the utmost profusion of arabesque ornament; and, on the exterior, the light minarets present a pleasing contrast to the large mass formed by the pile of domes over the centre of the edifice.

Civil edifices of the Turks.

The Turkish dwelling-houses, in towns, are lofty buildings of several stories, crowned by sloping roofs with bold projecting eaves, and have very much the appearance of the houses in Italy. Some are built entirely of timber, with verandas in front, and others have the lower parts of brick, and the upper of wood; the roofs are covered with tiles.

Turkish Fountains.

Elegant specimens of Turkish Architecture are seen in some of the Fountains at Constantinople; one of the finest is of a square figure on the plan, and is flanked by four towers, each of which presents three sides of a hexagon towards the exterior, and is ornamented with columns at the angles. At the top of the building is a broad entablature, with a great projecting roof, the angles of which are cut to correspond with the forms of the towers and columns. Above the centre of the roof, and over each tower, is a polygonal tambour covered with a cupola, and terminated by a small gilt spire. The doorway is crowned by a pointed arch, above which is an inscription in gilt letters; and the entablature is highly enriched with dentels and diamond figures in relief.

Khan of Damascus.

In the façade of the Khan at Damascus is a pointed arch with three polygonal columns on each side; the shafts of these are crossed by zig-zag grooves, and the capitals, which are very tall, are ornamented with long, pointed leaves, like those on some of the Egyptian columns. On each side, are niches with trefoil heads, and above these, are small circular windows enriched with ornaments. Over the door is a flat, segmental arch, and above this is a perforation of a similar form, but inverted. Between the horizontal string above the door and the soffit of the arch is a mosaic-work, representing the interior of a dome. The oblique faces of the voussoirs, instead of being planes tending to the centre of the arch, as is universally the practice in Europe, are cut in mouldings forming deep notches and high projections, which are fitted to corresponding projections and notches in the contiguous voussoirs. This practice, which is very common in the East, and seems to have been borrowed from the ancient Arabian Architecture, has, no doubt, arisen from a desire effectually to prevent the voussoirs from getting out of their places. In Europe, better notions are entertained of the stability of the arch, and, in our buildings, the mutual pressures of the great blocks of stone we employ would presently cause the destruction of all such mouldings.

Persian buildings.

The modern Palaces of Persia are rectangular buildings with flat, projecting roofs, and, in general, they have few pretensions to elegance of design. In the centre is a lofty hall, open in front, and its roof, which constitutes part of the general roof of the edifice, is supported by wooden pillars of square or octangular forms, painted and gilt, and with capitals resembling inverted frusta of pyramids. The dwelling apartments are on each side of the hall; on the wings are rooms for servants, and for the reception of baggage, and the entrances, windows, and other apertures are, generally, covered with pointed arches in the Gothic style. This feature seems now to prevail, in the East, to as great an extent as it once prevailed in Europe; and with similar modifications, being composed of two simple arcs of circles, or two curves of contrary flexure, and, frequently, having the sides cut to form several cusps towards the centre.

The houses of the common people are, generally, square, built of stones or sun-dried bricks, with flat roofs of timber, where that material is sufficiently abundant; but where it is not, the roofs are formed by small brick domes, which cause a village to appear, at a little distance, like a cluster of bee-hives.

According to M. Tournefort, the Caravanserais, or places for the public reception of travellers, consist of a number of apartments, each about 8 feet square, with vaulted roofs, surrounding a great quadrangular enclosure, and elevated about 4 or 5 feet above its level. The chambers are without windows, and receive their light only from the door. In front of each, in the interior of the court, is a small vestibule, about 4 or 5 feet deep, of the same breadth as the chamber, and having a chimney on one side; and, again, in front of these vestibules, is a general corridor, before which the horses are kept. The centre of the court is occupied by a cistern of water, sunk in the ground.

Buildi India.

The reign of the Emperor Akbar, in the XVIth century, is an Epoch from which may be dated the erection of several splendid Palaces and Religious edifices, which yet remain as monuments of the wealth and public spirit of that Monarch. The Palace in the City of Agra is situated in the middle of a large area, surrounded by colonnades, and having six entrances adorned with as many Triumphal Arches. In front of the principal building are two Grand Galleries, ornamented with columns of white marble, with bases of blue granite, and capitals of yellow mica, and, about it, are seven smaller

Palaces. Near this stands the Mosque of Akbar, the walls of which are of red granite, and were covered from top to bottom with gold plates. In the same City were several superb Mausoleums, and the Mosque of Aurenzebe, the roof of which was supported by more than one hundred columns.

The famous Observatory, at Benares, was, also, a work of the Emperor Akbar. According to the description of Sir William Baker, it is an assemblage of stone buildings surrounding several quadrangular enclosures: on the top of one is a terrace, part of which is covered by a dome of masonry turning on a pivot; within the dome are placed several stone instruments for Astronomical purposes, among which are two quadrants 9 feet 2 inches radius, with graduated arcs; and on an open platform is a gnomon or obelisk 20 feet high.

Lord Valentia describes the houses of this city as built of large stones, and some of them six stories high, the separation of the stories being distinguished on the exterior by a band of ornamental carved work; the roofs are flat, and serve as terraces for exercise, and the opposite houses on each side of the streets are sometimes united by Galleries.

In the further Peninsula of India, where the lower grounds are yearly overflowed, it becomes necessary to build the houses on high pillars, to keep the floors above the surface of the water; and this seems to have led to an almost universal adoption of that mode of building. The houses are raised from the ground on posts of bamboo, and the roofs are slightly covered with thatch. The Shoé Dagoon, or great Temple at Rangoon, in Ava, is described by Lieutenant Alexander as an immense edifice of a pyramidal form, entirely solid, and about 330 feet high; the lower part, to about half the height, is octagonal, and its exterior surface is cut in the form of steps about the whole circumference; the upper part is in the form of a bell, and ends in a spire, on the top of which is a sort of umbrella of open ironwork, surmounted by a vane and a globe of glass. Round the base of the edifice are many small pagodas of similar forms.

goda at
oang, in
ina.

The public buildings of China almost invariably consist of a number of apartments or cells surrounding a rectangular area; the general roof of these buildings projects beyond the wall towards the court, and the extremity is supported by a colonnade formed of wooden pillars, standing on marble bases. Such is the great Pagoda at Honang, in the suburb of Conan; its interior area is 590 feet long and 250 feet wide, and this is surrounded by cells for two hundred Bonzes, which have no light, except what is obtained from the doors. The entrance to the quadrangle is by a vestibule in the middle of one of the short sides, and at each angle is a building 30 feet square, for the residence of one of the principal Bonzes. In the middle of each of the long sides is a rectangular area surrounded by cells; one of the areas contains the kitchens and refectories; and the other, the hospitals for animals and a burying-ground.

In the interior of the great quadrangle, are three Pavilions, or Pagodas, each 33 feet square on the plan, and consisting of two stories, the lowest of which is surrounded by a peristyle of twenty-four columns; each Pagoda stands on a basement 6 feet high, to the top of which there is an ascent by a flight of steps on each side, and all the basements are connected together by a broad wall, of the same height as the basement, for the purpose of communicating between the Pagodas without descending into the court. The roof of the peristyle about each Temple is of a concave form on the exterior, and, at each angle, the projection is curved upward, and terminated by some animal figure: the sides of the upper story are formed by wooden posts, between which are open frameworks; round the foot of this story, on the exterior, is a balcony with a rail in front, and the roof is similar to that of the peristyle, each angle being turned up and ornamented. All the buildings are covered with varnished green tiles.

Pagoda at Nankin.

But many of the Pagodas in China are remarkable for consisting of several stories in height; that at Nankin, which has been described by M. Le Compte, is of an octagonal form; the length of each face on the plan is 15 feet, the whole height about 200 feet, and it consists of ten stories, each smaller than the one below it. The whole tower stands upon a basement surrounded by a covered gallery, and the ascent to the platform of the basement is by steps on each side; in each face of the lower story, are three semicircular-headed apertures, and each story is crowned by the usual projecting concave roof, the edges of which turn upward, as if to retain the rain-water. The lower part of the wall is 12 feet thick, and the upper part 8½ feet; its exterior is faced with porcelain, and its interior enriched with Paintings. The walls of the upper stories are pierced with niches which are filled with Idols sculptured in bas-relief and gilt; a cupola is placed above the uppermost story, and from its top rises a great mast to the height of 30 feet above the top of the tower. The floors are of planks supported on great beams which extend across the building, and the ascent from one story to another is by small staircases with high and inconvenient steps. This Pagoda is supposed to have been built about four hundred years since. See pl. xxi.

The Palace at Pekin.

All the Palaces and private dwelling-houses of the Chinese seem to be constructed nearly according to one plan; even the residence of the Emperor himself differs from the others only in being more extensive. From Mr. Barrow's *Account of Lord Macartney's Embassy*, it appears to be a vast enclosure of a rectangular form surrounded by double walls, between which are ranges of offices covered by roofs which slope down towards the interior. The included area is occupied by buildings not more than two stories high, and forming several quadrangular courts of various sizes, in the centres of which are buildings on platforms of granite 5 or 6 feet high; each of these is surrounded by columns of wood supporting a projecting roof, turned up at the angles, as usual: one of these buildings, which serves as a Hall of audience, stands on a platform, like the rest, and its projecting roof is supported by a double row of wooden columns; the intervals between the columns in each row is filled with brickwork to the height of four feet, and the space above the wall is occupied by a lattice-work covered with transparent paper. The courts are intersected by canals, over which are several marble bridges; the gateways forming entrances to the quadrangles are adorned with marble columns on pedestals, and decorated with dragons; and in the courts are pedestals supporting sculptured lions 7 or 8 feet high; at the angles of the buildings surrounding each area are formed square towers two stories high, and crowned by Galleries.

From Sir William Chambers's account of the dwell-

Dwelling-houses at Canton.

ing-houses of the merchants at Canton, they seem to be in the form of a long rectangle on the plan; they are two stories high, and the ground-floor is divided into two nearly equal parts by a wide passage extending through its whole length. In the front next to the street are the shops, and beyond these is a quadrangular, open vestibule leading to the private apartments. On each side of the passage, is a saloon for the reception of visitors, a sleeping-room, and, sometimes, a little closet or study: besides these, there are, on the ground-floor, the dining-rooms, the kitchen, the servants' rooms, and the bath. The saloon is commonly 18 or 20 feet long, and about 20 feet wide; the side next to the vestibule is open, or only occupied by a screen of canework, to secure it from the rain or sun; and in the back of the saloon, are doors which extend from the floor to about half the height of the ceiling; the upper part is a trelliswork covered with painted gauze, which lets in light to the bed-room. The partition-walls, which extend no higher than the ceiling of the ground-floor, are lined with mats to the height of three feet; the rest is covered with painted paper, and the pavement is composed of squares of stone or marble of different colours. The doors are generally rectangular, made of wood, and varnished or painted with figures; but a remarkable circumstance is, that the communication between the apartments is, sometimes, in the form of an entire circle, which has been compared to the aperture of a bird-cage. The windows are rectangular, and occupied by framework representing squares, or parallelograms, polygons, and circles, variously inscribed in, or intersecting each other; and similar forms are given to the rails which protect the galleries about the upper and lower stories; the compartments of the windows are generally filled with a transparent oyster-shell, which admits the light to the rooms.

The upper floor consists of several large apartments, which occupy all the breadth of the house, and, by temporary partitions, are converted into rooms for visitors, distinct from those occupied by the family; over the shops are sleeping-rooms for those who serve in them: the roof is supported on wooden columns; its extremities project beyond the walls, and at each angle is commonly the favourite emblem, a dragon. A plan and elevation of one of these houses is given in pl. xxi.

Triumphal Arches.

Triumphal Arches, or buildings erected to celebrate particular events, are very common in China, and, in the *Account of Lord Macartney's Embassy*, several such are said to have been placed across the principal streets of Pekin: these were all of wood, and each consisted of three gateways, the middle one larger than the others. Those at Ningpo are ornamented with polygonal columns of stone supporting an entablature which is composed of three or four faciæ, generally without mouldings, except the last but one, which is a sort of frize, filled with inscriptions: the buildings are crowned by roofs of the usual form, that is, with broad projections, and the angles pointing upward; and the apertures are either rectangular or terminated by semicircular heads. The use of arched vaults is not unfrequent in China. According to Duhalde, their voussoirs are of stone, about 6 feet long and 6 inches thick, and their sides, instead of being planes, like ours, are cut in curvilinear forms. Probably, they resemble the arch-stones described in speaking of the buildings in Turkey.

Part I

Chinese [illegible]lumns.

The Chinese columns are, in almost every case, of wood; but, when they form the peristyle of any considerable building, they stand on stone or marble bases of various profiles; they are entirely without capitals, unless we consider as such the brackets projecting from the upper part of the shaft on opposite sides, and assisting to support the architrave. The height of the whole column is equal to from eight to twelve times its lower diameter, and the shaft is in the form of a frustum of a cone; the base consists of a square plinth, above which is, sometimes, a moulding, in the form of an inverted cymatium, between two fillets; in other cases, the mouldings consist of the inverted cymatium and a torus, with a scotia and fillets between them; and, occasionally, there is placed, immediately above the base, a polygonal or cubical block, projecting beyond the surface of the shaft. The architrave is a cylindrical beam, like a pole, which passes through a hole bored near the top of each shaft, and is further supported by resting on two brackets, generally ornamented, which are inserted in the shaft below the architrave, and bent upward, so that the architrave may rest on the extremities. See pl. xxi. Above the architrave is sometimes placed what may be called a frize, consisting of an open framework panelling, formed by circles or squares of wood intersecting each other, and the intervals between the panels are ornamented with bells and heads of animals. Over the frize is the high and projecting cornice, of a concave figure, sloping downward in front, and turned up at the angles; the points are ornamented with heads of fish, or with dragons.

Roofs.

Some of the Chinese roofs are of an undulating form, the transverse section presenting the form of a double curve of contrary flexure, highest in the middle; these are supported by several pairs of cylindrical beams or poles notched into each other, and alternately parallel and perpendicular to the length of the building; the longitudinal poles being placed nearer together in proportion as they approach the top of the roof. The upper poles support the materials which form the covering.

Great wall

One of the most remarkable monuments of Chinese Architecture is the great wall, which begins in the sea to the East of Pekin, and extends along the frontiers of three Provinces, often in places which would be inaccessible to an enemy. Near the Eastern extremity it consists of rough stones faced with brickwork; its height is from 20 to 25 feet, and there are towers at intervals along it, which are built of brick on a basement of stone.

Chinese A chitecture derived fr the tent.

On contemplating the buildings of China, we cannot help being struck with their general resemblance to the tents, which we may suppose to have been the dwellings of a nomadic people; and it may reasonably be believed that when the ancient inhabitants of the Country assumed a stationary mode of living, they made their fixed habitations resemble the movable abodes to which they had been before accustomed. The columns which support the roofs are still made of wood; and, instead of the massive entablatures of Egypt and Greece, we find cylindrical rods so slender as to be only capable of supporting a roof of the lightest kind. The external covering of the roof has the undulating form of the cloth which is drawn over the poles of a tent, and its extremities turn up like the hooks to which cords are attached for uncovering them. The tallest Pagodas may be considered as several such tents piled one on another

The Arts of imitation have been stationary in China, probably, ever since the establishment of the Empire.

adition of Arts in ina.

A system of regulations, which it is a crime to infringe, pervades every Art, as well as every branch of Civil and Political economy, represses every attempt at original invention, and prevents any improvement on the ancient practice. Hence it is easy to conceive that all the works of this people will be characterised by a servile adherence to some primitive model, and it can excite no surprise that nothing in them indicates that tendency towards perfection which we observe in the works of European artists.

The case is rather different with the Architecture of India, which is characterised by some of the boldness, originality, and even extravagance of the Saracenic manner; and though arbitrary Governments in India and China have thrown their deadening influence over the minds of the artists of both those Countries, yet since the former is divided into many independent States, the differences of character and talent among the Princes have afforded scope for variety of design which is not to be found in the works of the Chinese, who are all subject to one Sovereign, and governed by unvarying laws.

Architecture.

EXPLANATION

OF THE

CHIEF TECHNICAL TERMS USED IN ARCHITECTURE.

ABACUS. A block forming the upper part of the capital of a column. It is generally rectangular, and its four vertical faces are either plain or moulded; but, in some cases, they are arcs of circles, the concavities of which are towards the exterior.

Acroter. A plain pedestal placed at the vertex, and at each of the lower extremities of a pediment, for the support of a vase or statue.

Alcove. A recess in an apartment for a bed or couch.

Amphiprostylos. A denomination applied to Temples or other buildings having columns at both extremities.

Annulet. A moulding, the profile of which is rectangular, surrounding a column in the base or capital.

Antæ. A denomination applied to pilasters when attached to the extremities of walls. A building the side walls of which are thus terminated, and having no columns in front of such pilasters, is said to be *in antis.*

Apophygis. A projection about the lower extremity of the shaft of a column, connecting the shaft with the base; its profile is concave outwards.

Apteral. A denomination applied to buildings having no wings, and to Temples having no columns along the flanks.

Arch. A series of bricks, stones, &c., generally cut in the form of frusta of wedges, which are disposed in a curvilinear manner, and in a vertical plane. It is denominated a circular, elliptical, cuspid, &c. arch, according to the nature of the curve; and the spandrils are generally included as part of the arch.

The cuspid or pointed arches are said to be of the third point, fourth point, &c., according as the radius of each curved side is equal to two-thirds, three-fourths, &c., of the span or interval between the supports.

Architrave. A beam of timber, or a course of masonry, laid in a horizontal position along the tops of the columns in a range.

Archivolt. The curvilinear course of materials immediately over the aperture of an arch, and supporting the spandrils.

Areostylos. A denomination applied to colonnades, when the intervals of the columns are not less than four diameters.

Astragal. A small moulding generally surrounding a column in the base or capital; its profile is semicircular, with the convex part outwards.

Attic. A story above the general cornice of a building; also a wall, ornamented with pilasters above the cornice.

Baluster. A small column supporting a rail of timber or a course of masonry; it is generally ornamented with mouldings and its profile is a curve of contrary flexure. A series of such columns is called a *Balustrade.*

Band. Any horizontal member in a building, having a rectangular profile and small projection.

Architecture.

Base. That member which is placed under the shaft of a column; it is generally ornamented with mouldings. When it consists of two tori separated by a scotia and fillets, it is called an *Attic base.*

Basement. The lowest story in a building.

Battlements. Indentations, generally of a rectangular form, made in the upper part of a parapet wall.

Bressummer. A beam of timber resting on posts and supporting a wall.

Buttress. A pier of brick or stone work attached to the face of a wall in order to strengthen it. When it has the form of a curve, and is attached to the wall only at its upper extremity, it is called an *arched* or *flying* buttress.

Cabling. An ornament cut in the form of a half-cylinder within the lower part of the fluting of a column.

Cantiliver. A timber projecting from the wall of a building to support the lower part of the roof.

Capital. The upper member of a column or pilaster; it is placed immediately above the shaft.

Caryatides. Sculptured female figures, sometimes employed as columns to support an entablature.

Cathetus. A vertical line drawn through the centre of a volute in an Ionic capital.

Cavetto. A concave moulding generally in the form of a quadrant of a circle, the upper part projecting over the lower.

Caulicolus. A sculptured ornament in the Corinthian and Composite capital, representing the stem of a plant.

Ceiling. The upper surface of the interior of an apartment. It is either *plane* or *vaulted;* but if the central part is horizontal, and the margins are connected with the side walls by cylindrical portions, the ceiling is said to be *coved.*

Cella. The principal division of a Temple within the walls; it is also called the *Naos.*

Coffer. An ornamental panel sunk in the ceiling of a building or apartment, or in the soffit of a projecting member.

Colonnade. A series of columns in line. When an area is surrounded by columns, that enclosure is called a *peristyle.*

Conge. An inverted echinus or ovolo; also an inverted cavetto.

Console. An ornamental projection in front of the keystone of an arch, or on each side of a doorway.

Corbel. A projection from a wall, intended for the support of any object.

Cornice. The upper member of an entablature or pedestal; also a corresponding member at the foot of the roof about the exterior of a building in which no Order is employed, or along the tops of the walls in an apartment.

Corona. The projecting member which forms the upper part of a cornice; it is called also the *drip* and *larmier.*

Corridor. A gallery within or about a building.

Cortile. A court enclosed by the divisions of a building.

Crocket. A sculptured ornament resembling curled foliage placed on the sides of a pediment or pinnacle.

Cross-springers. The diagonal ribs formed at the ridges of a groined vault.

Crypt. The subterranean part of a building.

Cupola. Any dome is so called, but the term is generally applied to one of small dimensions.

Cymatium. A moulding, the profile of which is a curve of contrary flexure: it is of two kinds, denominated *cima recta* and *cima reversa*, according as the upper part is convex or concave outwards.

Dado. The body of a pedestal; its form is that of a cube or parallelopiped.

Dentel. A small block in the form of a parallelopiped. A row of these forms an ornament in the cornice in some of the Orders.

Diastylos. A denomination applied to a range of columns, the intervals of which are equal to from three to four diameters.

Dipteral. A denomination applied to such edifices as have two rows of columns on each flank.

Dome. A vaulted covering placed over the whole or part of a building; its form is either spherical or paraboloidal.

Eaves. The lower extremities of a sloping roof.

Echinus. A convex moulding employed in the capital of a column or pilaster, and in the entablature. Its profile is an arc of some conic section, and the upper part projects beyond the lower.

Entablature. The system of timbers or masonry supported by the columns of an Order, and generally carrying the roof.

Entasis. The protuberance or swell produced by the curved form given to the profile of the shaft of a column.

Epistylium. The same as *Architrave*, which see.

Epitithedas. The upper moulding of an entablature; generally applied to that over the flanks of a building, the extremities of which are crowned by pediments.

Eustylos. A denomination applied to a range of columns, the intervals of which are equal to two diameters and a half.

Extrados. The curve formed by the upper extremities of the voussoirs of an arch, also the superior curved surface of a vault or dome.

Façade. The principal front of an edifice.

Fascia. The exterior, and generally, vertical face of any member which is rectilinear in direction and profile.

Fillet. A narrow and plain moulding, either surrounding a column, or extending along the face of a building; its profile is rectangular. The plain part of the shaft of a column between two flutes is also so called.

Finial. The sculptured ornament resembling a knot of foliage placed at the apex of a pediment or pinnacle.

Fleuron. A sculptured ornament resembling expanded foliage or flowers.

Flutes. The longitudinal channels cut on the shaft of a column.

Fretwork. The denomination applied to a fillet or system of fillets sculptured in lines, waving or broken in directions generally at right angles to each other. When the fillets resemble battlements, the ornament is called an *embattled fret;* and when interwoven with each other, it is called a *guilloche.*

Frize. That horizontal member in an entablature which is situated between the architrave and cornice.

Fust. The same as *Shaft*, which see.

Gabel, or *Gavel.* The triangular part of the wall, included between the extremities of the sloping sides of the roof, on the face of a building. When the triangle is enclosed by regular cornices it is called a *tympanum.*

Girder. The principal beam in a floor, intended to support the joists.

Guilloche. See *Fretwork.*

Guttæ. Pendent ornaments of a conical, cylindrical, or trochoidal form, placed under the mutules and teniæ in the Doric Order.

Hypæthral. A denomination applied to buildings formed partly without a roof.

Hypotrachelion. That part of the capital of a column between the principal ornaments and the mouldings or grooves which mark the top of the shaft.

Jambs. The pieces of timber or masonry forming the sides of a door or window, generally placed in vertical positions.

Impost. The block, or system of mouldings on the top of a pier, which serves for the support of an arch.

Intercolumniation. The interval between the nearest sides of two columns in a range.

Intrados. The curve formed by the lower extremities of the voussoirs of an arch; also the inferior surface of a vault or dome.

Joists. The timbers supporting the boarding of a floor, or to which the laths forming a ceiling are attached.

Key-stone. The voussoir placed at the vertex or crown of an arch or dome.

King-post. The vertical timber between the centre of a tie-beam and the summit of the roof.

Label. A moulding placed above, and concentric with the extrados of an arch or window in Gothic Architecture: when the upper part of the window was rectilinear, the label was horizontal.

Lacunar, or *Laquear.* A coffer or panel sunk in a ceiling of an apartment, or in the soffit of any member; the term has been applied to the whole ceiling or soffit.

Lantern. A small cylindrical or prismatical turret at the top of an edifice.

Lintel. A timber or stone supporting the wall over any aperture, the upper part of which is horizontal.

Listel. The same as a Fillet or Annulet.

Loggia. An open gallery.

Medallion. A circular or elliptical panel in a wall or ceiling.

Metope. The interval between two triglyphs in the Doric frize.

Mezzanine. A story formed in some buildings between two principal ones.

Modillon. A projecting member in the entablature of the higher Orders, placed at intervals under the corona as if to support it.

Module. The unit of length by which the proportions of the members in an Order are expressed: it is generally equal to a semidiameter of the lower part of the shaft of the column, and is subdivided into thirty parts called minutes.

Monopteral. A denomination applied to buildings surrounded by a single, circular colonnade on the exterior.

Mosaic. A species of ornament applied to pavements and the interior sides of walls, formed of inlaid stones or other materials of various colours.

Mouldings. The ornamental projections applied about columns or pedestals, or on the entablatures and walls of buildings.

Mullions. The posts, pillars, or bars placed in the apertures of windows; they are denominated *vertical*, *horizontal*, or *radiating*, according to their position.

Mutule. A thin, projecting member placed at intervals under the corona in the Doric entablature.

Naos. The same as *Cella*, which see.

Niche. A recess in a wall.

Ogee. The same as *Cymatium.*

Opisthodomus. A division of a Temple in which the treasures were kept.

Orchestra. The part of a modern Theatre which is appropriated to the musicians. In the Greek Theatre the dances were performed in it; and in the Roman Theatre it was occupied by the seats of the Senators.

Order. A system of members in Grecian and Roman Architecture, consisting chiefly of the column with its base and capital, and the entablature; and constituting the particular character of the edifice. Five Orders have been invented, which are distinguished by the names Tuscan, Doric, Ionic, Corinthian, and Composite.

Oriel. A projecting window, rectangular or polygonal on the plan, and supported by timbers or masonry inserted in the wall.

Ove. A sculptured ornament resembling an egg.

Ovolo. A convex moulding, the profile of which is a quadrant of a circle, having the projecting part uppermost.

Panel. A shallow recess with a plane surface, and generally rectangular, formed in a ceiling, wall, or piece of woodwork.

Parapet. A low wall surrounding a terrace, or the roof of an edifice, or extending along each side of a bridge.

Parastata. The same as *Pilaster:* the term is sometimes applied to a post placed by the side of a column to support the floor of a gallery less elevated than the column.

Pavilion. A wing of an edifice, connected with the principal part by a wall or colonnade.

Pedestal. A low pillar with vertical sides placed under a column or obelisk; it is usually rectangular, and ornamented with a base and capital.

Pediment. The triangular part of the wall above the general, horizontal cornice at the extremities of a building, when the roof is formed with sloping sides.

Pendentive. A portion of a spherical vault formed at each intersection of two cylindrical vaults crossing each other at right angles, when a circular aperture inscribed in a square vertically over that formed by the intersection of the vaults at bottom, is made on the level of their crowns. The face of the pendentive is thus bounded by three circular arcs.

Pergamena. A small turret crowning a dome.

Peripteral. A denomination applied to such rectangular buildings as are surrounded by a colonnade on the exterior.

Peristyle. A court in the interior of a building, generally quite surrounded by columns.

Piazza. A large area surrounded by buildings.

Pier. A mass of masonry supporting one extremity of an arch or vault; the part of a wall between two windows or doors is so called.

Pilaster. A pillar bounded by plane surfaces; it is sometimes isolated, but generally attached to a wall.

Pillar. The general name for a column or pilaster.

Pinnacle. A small cone or pyramid placed above a turret, buttress, or the roof of a building.

Planceer. The same as *Soffit*, which see.

Plinth. A block, generally bounded by four plain vertical faces, and placed under the mouldings in the base of a column or pilaster, or under a whole building.

Podium, or *Pluteus.* A continuous pedestal supporting columns: also, a parapet wall about a terrace was so called.

Porch. A small covered projection in front of a doorway.

Portico. A term generally applied to the projecting part before the entrance of a considerable edifice, when it is covered by a roof supported on columns. Anciently, the *Porticus* signified any colonnade.

Posticum. A portico in rear of any building.

Pronaos. The division of a Temple in front of the naos or cella.

Propylæum. A portico in front of the principal entrance to a city.

Proscenium. That part of the stage which is in front of the scenery in a Theatre.

Prostylos. A denomination applied to buildings having columns at one extremity only.

Pseudodipteral. A denomination applied to buildings having two rows of columns at each extremity, and only one along each flank.

Pulvinated. A term applied to the frize in an Order when its profile is a segment of a circle, convex outward, so that it appears swollen.

Purlines. Timbers extending longitudinally across the principal rafters to support the smaller ones.

Pycnostylos. A denomination applied to a colonnade, in which the intervals of the columns are equal to a diameter and a half.

Queen-post. A vertical post supporting a rafter, but not placed over the middle of a tie-beam.

Quoins. The salient and rentrant angles formed by the walls of a building.

Rafter. A timber disposed in a vertical plane, and extending from the ridge to the lower extremity of the roof of a building.

Regula. The same as *Fillet*, which see.

Roof. The covering of a building. A *trussed* roof is that which is formed of several triangular frames placed vertically at intervals above the walls, to support the rafters and covering. A roof is said to be *hipped*, when it consists of four planes inclined to the horizon; and it is called a *mansard*, or *curb-roof*, when a transverse vertical section has the form of four sides of a polygon.

Rubble-work. A denomination applied to walls formed of unwrought stones.

Rustic-work, or *Rusticated-work.* A denomination applied to that in which the exterior of the masonry is left rough, or purposely made so. And to that in which the joints of the masonry are strongly marked by grooves.

Scotia. A concave moulding in the form of a segment greater than a quadrant of a circle or ellipse.

Shaft. The trunk of a column; that is, the part between the base or pavement and the capital.

Socle, or *Zocle.* The same as *Plinth.*

Soffit. The inferior surface of any projecting member.

Spandril. The part between the crown and foot of an arch or vault, and above the course of voussoirs. A *pendent* spandril, in Gothic Architecture, is the key-stone of a vault cut in a conical, pyramidal, or bell-shape; its point, which is placed downward, descends below the ceiling at the place of insertion.

Stereobata. The basement, or lower part of a building.

String, or *Cordon.* A projection of masonry, extending horizontally along the face, or entirely about a building.

Stylobata. The same as *Podium*, which see.

Systylos. A denomination applied to a colonnade, when the intervals of the columns are equal to two diameters and a half.

Tabernacle-work. The denomination applied to the rich sculpture about a Tomb, or Shrine.

Tænia. The same as *Fillet.*

Tambour. A cylindrical wall, placed above the general roof of a building, to support a spire or dome.

Tie-beam. A timber, extending horizontally between the tops of two parallel walls.

Torus. A convex moulding about a column; its profile is either semicircular or semielliptical.

Tracery. The ornamental work formed by the intersections of the mullions in windows, and of the mouldings at the ridges, or on the spandrils of groined roofs.

Transept. That part of a Church which is carried out on each side perpendicularly to the length.

Transom. The horizontal bar placed across a window.

Trefoil. An aperture or ornament, bounded by three segments intersecting each other.

Trellis-work. A species of ornament on the face of a wall, formed by courses of fillets crossing each other at any angle.

Triforia. An upper tier of arcades in an Ecclesiastical edifice, when the arches are subdivided into three parts by two columns or posts.

Triglyph. A rectangular ornament, placed at intervals along the frize in the Doric entablature; in its face are cut two vertical channels.

Tympanum. The triangular space included within the horizontal entablature on the face of a building and the cornices of the pediment. See *Gabel.*

Vault. A roof in the form of some portion or portions of a cylinder or sphere. It is said to be *waggon-headed* when it consists of a hemicylinder resting on the walls, and *domed* when it consists of a segment of a sphere or paraboloid.

A *cloister* vault is that formed by four portions of cylinders rising from a square base and meeting in a point at the vertex: and a *groined* vault is one made by two hemicylinders intersecting each other at right angles.

Vestibule. The entrance-hall of an edifice.

Volute. The ornament formed by a moulding bent in a spiral form, which is situated at each angle of the capital, in the superior Orders.

Voussoirs. The stones cut in the form of frusta of wedges, and constituting the curved part of an arch or dome.

Water-table. A sloping surface formed on the face of a wall, buttress, &c., where the projection diminishes.

Weather-moulding. The same as *Label*, which see.

Zophorus. The same as *Frize*, which see.

LIST OF SOME OF THE CHIEF WORKS ON ARCHITECTURE.

Architecture.

A. D.
1431. Architectura Moderna. Hendrich de Keyser.
1485. De Re Ædificatoriâ. Alberti.
1486. De Architecturâ. Vitruvius Pollio.
1537. Architectura. Serlio.
1554. I Quatuor Primi Libri de Archit. Pietra Cataneo.
1559. Livre d'Architecture, contenant les Plans et Desseins de 50 Bâtimens tous Différens. Androuet du Cerceau.
1563. The first and chief Grounds of Architecture. John Shute.
1567. Architecture, with Annotations. Dan. Barbaro.
1569. Règle Générale d'Architecture. Jean Bullant.
1568. Ten Books of Architecture. Philibert de l'Orme.
1570. Architecture. Palladio.
1572. Dispareri in Materia d'Architectura, etc. Martin Bassi.
1577. Architecture de Vitruv. Johannes Frisius Vredeman.
1582. De Compendiosâ Architecturâ et Complimento Artis Lullii. Jordan Bruno.
1593. Architecture. Wendel Ditterlein.
1699. Architecture von Verstungen. Dan. Speckle.
1615. L'Idée de l'Architecture Universelle. Scamozzi.
1617. Instruction sur les Cinq Rangs de l'Architecture. Henry Hondius.
1624. Elements of Architecture. Sir Henry Wotton.
1624. L'Architecture Françoise. Louis Savot.
1631. Regola delli Cinque Ordini d'Arch. Vignola.
1631. Architectura Moderna. Cornelius Danckaerts.
1642. Le Secret d'Architecture. Mathurin Jousse.
1643. L'Architecture des Voûtes. François Derand.
1644. Architectura Politica. Gilbert Chazerat.
1661. The Elements of Architecture. John Evelyn.
1664. Architectura Curiosa Nova.
1669. New Treatise of Architecture according to Vitruv. R. Prike.
1673. Les dix Livres d'Arch. de Vitruv. Claude Perault.
1675. Cours d'Architecture Française. Blondel.
1676. Résolutions des Quatres Principaux Problêmes d'Arch. Blondel.
1676. Plain Description of the Five Orders. Bosbom.
1676. Les Principes de l'Arch. Felibien.
1685. Œuvres d'Architecture. D'aviler.
1687. The Mirror of Architecture. Vinc. Scamozzi.
1691. L'Architecture Pratique. J. B. Bullet.
1696. A Treatise on Architecture. Nich. Goldmann.
1702. Studio di Arch. Civili. Rossi.
1714. Nouveau Traité de toute l'Architecture. Cordemoy.
1714. Traité d'Architecture. Le Clerc.
1715. Les Ouvrages d'Architecture. Pierre Post.
1717. Vitruvius Britannicus. Campbell.
1720. The Orders of Architecture. Palladio.
1720. Opere d'Architectura. Boromini.
1720. Sommaire d'un Cours d'Architecture. Belidor.
1720. Architecture Historique. J. B. Fisher.
1722. The Marrow of Architecture. W. Halfpenny.
1725. Observations on the Orders and Rules of Architecture in use among the Romans. Inigo Jones.
1727. An Essay in Defence of Architecture. Robert Morris.
1728. Book of Architecture. Gibbs.
1728. History of Amphitheatres. Maffei.
1732. General Treatise of Architecture. Thomas Rowland.
1732. Oxonia Depicta. Williams.
1733. Proportional Architecture. Lectures on Arch. Rob. Morris.
1739. Commentarius Criticus de Vitruvii Arch. Poleni.
1745. Livre d'Architecture. Germain Boffrand.
1751. Œuvres d'Architecture. Anthony Le Paute.
1753. Ruins of Palmyra and Balbec. Wood.
1757. A complete Body of Architecture. Ware.
1759. Treatise on Civil Architecture. Chambers.
1762. Antiquities of Athens. Stuart and Revett.
1764. Palace of Dioclesian at Spalatro. Adams.
1765. Observations sur l'Architecture. L'Abbé Logier.
1767. Vitruvius Britannicus. Woolfe and Gandon.
1768. Grecian Orders of Architecture. Stephen Riou.
1770. Les Ruines des plus beaux Monumens de la Grèce. Le Roy.
1772. The Architecture of Vitruvius. Newton.
1773. Le Vignole Moderne. Lucotte.
1773. Works on Architecture. Robert Adams.

Architecture.

A. D.
1779. Monuments of Roman and Moorish Architecture. Swinbourne.
1780. Cours d'Architecture Civile. Blondel.
1785. Principi di Architettura Civile. Milizia.
1786. Dell' Archit. Egiziana, Dissert. Belgrade.
1789. On the Origin of Gothic Architecture, &c. Pownall.
1789. Elementa Architecturæ Civilis. Aldrich.
1792. An Introductory Discourse on Gothic Architecture. Murphy.
1793. A Philosophical and Critical History of Architecture. Bromley.
1794. Complete System of Architecture. George Richardson.
1796. Remarks on the Architecture of the Anglo-Saxons and Normans. Wilkins.
1796. On the History of Ancient Castles and Progress of Architecture. Edward King.
1796. Remarks on the whole Progress of Architecture. E. King.
1799. Munimenta Antiqua. King.
1799. Remains of Egyptian Architecture. J. G. Grohmann.
1800. Voyage Pittoresque en Egypte. Denon.
1801. Essays on Gothic Architecture. Warton.
1801. Recueil et Parallèle des Edifices Anciens et Modernes. Durand.
1803. Remarks on Grecian and Gothic Architecture. Repton.
1803. De l'Architecture Egyptienne. Quatremère de Quincey.
1805. The Architectural Antiquities of Great Britain. Britton.
1806. Professional Observations on the Architecture of France and Italy. Tappen.
1806. Observations on English Architecture. Dallaway.
1806. Specimens of Continental Architecture. Smirke.
1807. Antiquities of Magna Græcia. Wilkins.
1809. Historical Survey of the Ecclesiastical Antiquities of France. Whittington.
1809. Principles of Architecture. Nicholson.
1811. Architectural Dictionary. Nicholson.
1811. Elucidation of the first Principles of English Architecture. Kendall.
1811. Treatise on the Ecclesiastical Architecture of England. Milner.
1813. Essay on the Origin and Principles of Gothic Architecture. Sir James Hall.
1813. Two Letters on the Subject of Gothic Architecture. Haggit.
1813. Civil Architecture of Vitruvius. Part I. Wilkins.
1814. Complete Course of Civil Architecture. L. C. Sturmius.
1814. Architectura Civilis. J. Wilhelms.
1814. Essays on Architecture. Grose.
1815. Le Fabbriche più Cospicue di Venezia. L. Cicognara.
1817. Unedited Antiquities of Athens. The Society of Dilettanti.
1817. Antiquities of Ionia. The Dilettanti Society.
1818. History of the Origin and Establishment of Gothic Architecture. Hawkins.
1818. Notabile Antiquità di Roma. Labacco.
1818. Arch. Diverse. Piranesi.
1818. Della Magnificenza ed Arch. de' Romani. Piranesi.
1818. Chronological Illustrations of English Architecture. Britton.
1818. Ancient Architecture in England. Carter.
1818. Essays on Gothic Architecture. Bentham.
1818. Arch. della Basilica de S. Pietro in Vaticano. Costaguti.
1819. Nouveau Parallèle des Ordres d'Architecture. Normand
1820. Architectural Antiquities of Normandy. Cotman.
1822. Inquiry into the Principles of Beauty in Grecian Architecture. Lord Aberdeen.
1823. Specimens of Gothic Architecture. Pugin.
1823. Parallel of Architecture. Wiebecking.
1824. Essay on the Origin and Progress of Gothic Architecture. Dr. Moller.
1824. Principles of Design in Architecture. Mitford.
1825. Treatise on the Decorative Part of Civil Architecture, by Chambers. Gwilt.
1826. Architecture of Vitruvius. Gwilt.
1827. Ruins of Selinus. Angel and Evans.
1827. Illustrations of the Public Buildings of London. Britton and Pugin.
1828. Architecture of the Middle Ages. Cresy and Taylor.
1830. Ruins of Pompeii. Gell.
1830. Stuart's Athens. Kinnaird.

SCULPTURE.

lpture. ition.

Sculpture, in its strictest and most confined sense, is the Art of carving or cutting any material into a proposed form, or shape, and may be practised in various ways; first, in representing entire or insulated figures, as in statues or groups, denominated by artists "the round:" secondly, in making figures either in high or low relief, (*alto* or *basso rilievo,*) that is, when the object represented is more or less raised, without being entirely detached from a back-ground; (of which some of the Sculptures from the Parthenon, now forming a part of the Elgin collection of marbles in the British Museum, afford excellent examples; those of the metopes being in high relief, and those of the frize in low;) and, thirdly, by cutting or sinking into a ground, making the object represented below the plane of the original ground; a mode of working seldom employed in modern times, but of which many specimens may be seen in Egyptian Sculpture.

sions.

In its more general acceptation, Sculpture is the Art of representing objects by form, and is thus indiscriminately applied to carving, to modelling, (or the plastic art,) to casting in metal, and to gem-engraving in hard or soft stones, as in CAMEI OR INTAGLI.

es.

Sculpture has very peculiar claims upon our regard; and no person interested in the History, the manners, or the customs of the Ancients, will estimate lightly an Art to which the antiquary and man of letters are so much indebted. Monumental remains, whether they contain Inscriptions, or represent Historical or Mythological subjects, have been found valuable landmarks, where no other sources of information have existed; and have often afforded satisfactory illustration of passages in the writings of the Ancients, which, but for such aids, would either have remained in total obscurity, or at any rate have been but partially understood. Ancient Sculpture is, therefore, as highly recommended by its usefulness, as by the charms which all persons of refined taste and feeling must find in it as an elegant Art, and its History cannot be considered a matter of indifference.

sity.

Various opinions have been held respecting the antiquity of the Arts of Design, and particularly whether Painting or Sculpture was first practised; it appears probable, however, from the comparatively easy task of repeating the real shape of any object in a solid material, with that of drawing on a plane its partial view and perspective appearance, (a process that requires some preparatory knowledge,) that Sculpture preceded Painting. The story of the daughter of Dibutades having traced the outline of her lover's profile from the shadow cast on the wall by a lamp, and of the outline being afterwards filled in with clay by her father, and sent with his pottery to be baked, is well known.[*] Such an account of the origin of the Art of Modelling, is very poetical, but not sufficiently probable; the potter's clay must have been one of the most obvious materials for imitative Art, and there can be little doubt that attempts were made to model it into the human shape in the earliest Ages.

Sculpture. Materials employed by the Ancients.

The Ancients appear, in their Sculpture, to have availed themselves of every material which was capable of being applied to the purposes of modelling, carving, or casting. Pliny has supplied us with much curious information on the subject; and Pausanias, and other writers who have interested themselves in Art, have frequently given, with their descriptions of statues and *bassi rilievi,* a particular account of the materials in which such works were executed. It would extend this Essay to too great a length were we to enter into such details, or even attempt to supply a correct catalogue of the materials used; the varieties of wood and marbles, for instance, were almost infinite; we shall, therefore, confine ourselves in this place to a mere general notice of them; referring the more curious reader to the authors who have entered more at large into the subject.[*] In a subsequent page we shall be necessarily led to speak of some of the most important works of the Greek Sculptors, and our attention will then be required to some mixtures or combinations of materials, which will be better considered while treating of the works, than in the present stage of our subject.

For modelling, clay, wax, and stucco, or plaster, appear to have been universally used; the clay, after having been worked into the proposed form, was frequently baked, acquiring by that process a hardness not inferior to stone; in this state, too, it often served for moulds, into which soft clay was squeezed, and thus the object became easily multiplied. A considerable number of ancient specimens of statues, *bassi rilievi,* lamps, tiles, and architectural ornaments, in this material, (called *terra cotta,*) have been preserved, and may be found in most collections of antiquities; in the Museum at Naples, particularly, are some statues from this material as large as life, which were discovered in the ruins of Herculaneum. Marbles, stones, and woods of all kinds, as well as ivory, were employed by the carvers; and all the known metals, wax, plaster, and even pitch, were used for the different processes of casting. There was a statue of amber of Augustus; and at the celebration of *Funeralia,* as in those of Sylla, at public exhibitions, or on other extraordinary occasions, we read of statues having been made of aromatics, and of materials of the most combustible nature; and amongst the odd conceits of the ancient artists, may be mentioned a statue of the all-powerful Goddess of Love and Beauty made of loadstone, which attracted a Mars of iron! The combination of different materials, for the purpose of producing variety of colours, either for drapery or ornaments, was termed *Polychromic Sculpture*;[†] and those works which were composed of a variety of stone or marble, were in like manner called *Polylithic.*[‡] This mixture of materials, which modern taste disapproves, was continually resorted to by the most celebrated artists during the best period of Art in Greece, particularly in colossal

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[*] Plinii *Hist. Nat.* lib. xxxv. c. 43. *Ed.* Hard.

[*] Plinii *Hist. Nat.* Pausanias. Junius, *De Pict. Vet.* Winckelman, Caryophilus *de Marmoribus,* &c.

[†] From πολὺς, many, and χρῶμα, colour.

[‡] From πολὺς, many, and λίθος, a stone.

works; we shall, however, defer for the present any observations on this branch of our subject.

Obscurity of origin. The History of the earliest practice of Sculpture is so obscure that we are left entirely to our conjectures respecting it; we endeavour in vain to elicit any authentic information respecting its first introduction, from the few notices of it that are scattered over the Works of the Ancients; and, when we consider the very late date of the oldest of those writers, compared with the undoubted antiquity of the Arts of Design, the fabulous accounts of some, the contradictory evidence or total silence of others, on the subject of their early History, will scarcely be wondered at. Of the existence of works of a very remote date, Tradition supplied them with notices; but these, in the course of Ages, had become so changed as they were handed down to succeeding generations, and so subject to exaggeration or misrepresentation, according to the feelings or fancy of the reporters, that but little reliance could be placed upon them at that time, and still less can we build upon them as data.

Probable History. The desire which men have always felt to perpetuate the memory of extraordinary persons, or of actions performed by them, and thus to honour their benefactors or heroes while living, and to hand down the fame of their exploits to future Ages, has been universal, and equally influential in rendering the Arts of Design, even in their rudest state, objects of interest and importance. Their first introduction was, in all probability, for the mere purpose of commemoration, and, in whatever the monument consisted, it was no doubt marked by great simplicity; any accession of importance from form or style was the effect of time, and depended on various circumstances connected with the degree of civilization which the people practising or attempting imitative Art had attained. We read in the oldest Historians,[*] of monuments erected to mark the spot whereon any extraordinary event had taken place; and although, at the early period alluded to, these monuments were only composed of rude blocks, sometimes of mere heaps of stones, still to such a commencement, so simple in the means, yet so important in its object, are we, in all probability, indebted for the existence of those Arts which, by gradual advances, became so universally practised, and in many parts of the World so highly cultivated. Religious feelings, too, had their share in forwarding the progress of the Arts; for uneducated Man, unable to comprehend a Divine Essence, was led to offer his addresses to some palpable substance, as a representative of that Power from whom he felt he derived all Good, or by whose influence he was protected from Evil. But it is conceived this was subsequent to the first and more natural introduction of commemorative monuments. It seems probable, too, that the first statues were of Men rather than of Gods, and that Human Idols preceded those of Divinities. The supposition is strengthened by the fact, that the earliest objects of worship amongst the Heathen Nations were the Heavenly Bodies; and, although there were symbols dedicated to them, or allusive to them, it does not appear in any instance that these were made in the Human form; on the contrary, it is more likely they were mere pillars of a conical or pyramidal shape; and it has been supposed that when such works are alluded to and called "graven images" by Moses, it is in reference to the allegories or hieroglyphics inscribed on them. Traditional accounts of wonderful exploits in arms, the real or fabled History either of a mighty conqueror, a lawgiver, or a founder of a Nation, led probably in the first instance to the attempt at making an image, which a rude and uncultivated people, always fond of the marvellous, would soon learn to contemplate with feelings of admiration and awe as the representative or type of their great Chief. Extraordinary respect for his memory and actions would lead to the payment of extraordinary honours; and as the promotion of Heroes into Divinities offered but little difficulty, when time had obscured the real existence of the objects, the crafty policy of a college or caste of an hereditary Priesthood, (such as existed in Asia particularly,) would soon be led to take advantage of the effect produced upon the imagination of the people by stories attached to rude and frightful attempts at form. Thus an extravagant and monstrous worship was introduced, which soon prevailed over a vast portion of the World in ancient times, and is even now met with in uncultivated regions. The oldest monsters of Egypt, no less than the images of the Buddhists and Chinese, were, probably, in the natural progress of superstition, (fostered by the Priesthood,) the fruits of a similar origin, and, perhaps, the same may be said, in the first instance, of the Gods of Babylon and Nineveh. *Primus in orbe Deos fecit timor*, is perfectly true of the Idol Gods of the East; to increase their effect in exciting terror by additional monstrosities, both of form and attributes, was the object of the Priests, and the only progress in Art amongst them was the introduction of additional incongruities. The general forms once consecrated as symbolical of the attributes, or as resemblances of their monstrous Gods, were afterwards preserved from improvement or innovation by the nature of their hierarchal institutions; and thus, as will be more particularly shown when we come to speak of Egyptian Sculpture, was a barrier raised against any improvement in style in the imitative Arts, which, as long as it was respected, was fatal to their progress.

Inventio the East. To return to our History. It has been contended that the Egyptians were the inventors of Sculpture: the distinction has also been claimed, and with much more propriety, for the Phœnicians, of not only having invented it, but of having extended it and taught it to other Nations. The circumstances which Asia appears to have enjoyed, undisturbed as that portion of the Globe was for a long period, either by intestine divisions or foreign wars, is also favourable to the opinion that the Arts, both useful and ornamental, had their commencement there, and that as it was the first settlement of Man after the Deluge, so it was the cradle of the Arts and Sciences. It is, indeed, more than probable that the Asiatics had made considerable progress in them long before they had any existence in other Countries. It is much to be regretted that our acquaintance with the earlier History and migrations of the Hindùs is so scanty; but we trust the time is not far distant when the laudable exertions of a learned Society, instituted for the express purpose of collecting information respecting the History of the Nations of the East, will be so far crowned with success as to enable the curious in such pursuits to penetrate the thick cloud in which the origin and intention of their Mythology is enveloped; and from which, however they may have been changed subsequently, it is not improbable that much in the Egyptian, and even the Grecian systems of

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[*] *Genesis*, ch. xxxv. v. 14; *Joshua*, ch. xxiv. v. 26, &c.

worship, was originally derived. Such a knowledge, if the supposition be admitted, would open a wide and extremely interesting field for the antiquary, and, leading to the explanation of the object of their Sculpture, would tend to elucidate much in the practice of the Arts amongst the earlier Nations.

posed Scrip- notices.

It has been asserted by some of the oldest Christian writers that Abraham,[*] as well as his father Thera or Terah, were themselves makers of images. The Scriptures afford us no authority for this supposition; we only find allusion made to their being infected with the extravagant and improper notions that are said to have prevailed in those days, both with regard to image-worship, and adoration paid to the stars. Thus in the Book of *Joshua*,[†] we read, "Thus says the Lord God of Israel, your fathers dwelt on the other side of the flood in the old time, even Terah, the father of Abraham, and the father of Nachor;" and "*they served other Gods*:" and in a subsequent verse of the same chapter they are counselled "to put away the strange Gods" that were among them. It is true that in this place no particular mention is made of the objects which they worshipped; but, soon after this time, we have it very expressly stated, that Rachel, when she left her father's house with Leah and Jacob, carried away the "images," and that Laban pursued them for the purpose of recovering them. This, we believe, is the earliest notice we have in the Holy writings of the existence of such things; and even here no details are supplied by which we can ascertain what they were like, nor of what materials they were formed. That they were but small, is evident from the circumstance of Rachel being able to carry them away unobserved, and afterwards from the facility with which she concealed them when Laban searched for them. One other instance may be mentioned, where Jacob is described as taking all the "strange Gods and hiding them under an oak which was by Shechem."[‡]

lpture ongst the ebrews.

No remains of the Sculpture of the Hebrews exist, but we are assured that, at the time of Moses, they were considerably advanced in their knowledge of, and practice in, some of the most difficult Arts. Of this, the setting up of the Golden calf, and the Brazen serpent, afford ample testimony. It has been well observed by the author of *Sabæan Researches*,[§] that the manner in which the Art of Engraving is spoken of in the Books of Moses, shows that it was by no means an Art of recent invention at those times. The onyxes for the sacred ephod, the plate of gold for the mitre of the High Priest, and the precious stones for his breastplate, were all ordered to be engraven like the engravings of a signet; and this expression is frequently used in the Book of *Exodus*: at chapter xxxix. it says, "they wrought onyx stones enclosed in ouches of gold, graven as signets are graven." The same observation has been made with regard to the Cherubim, which seem to have been well-known figures, in that day, to the Jews; for Moses does not give any particular description of them, nor detail of form, as he does of other things, and yet the Jewish artists appear to have made them correctly. At this time too, at least fifteen hundred years before the Christian Era, we find the names of two Hebrew Sculptors recorded, Bezaleel the son of Uri, and Aholiab the son of Ahisamach, both employed by Moses to make the ornaments of the Tabernacle, and which will be found particularly described in the XXXVIth, XXXVIIth, and XXXVIIIth Chapters of *Exodus*. These, it may be observed, are the earliest Sculptors of whom we have, by name, any authentic record. It is presumed that the Sculpture of the Hebrews bore a good deal of resemblance in point of style to that practised by the Egyptians, and which we shall examine more particularly when we come to treat of that people.

Assyrians and Babylonians.

Diodorus Siculus, describing the riches and beauties of Babylon and Nineveh, says, there were a variety of magnificent works in the celebrated Gardens of Semiramis; *bassi rilievi* of animals, which were richly painted, and statues in bronze of Belus, Ninus, and Semiramis, were amongst the decorations of the Palace. Now, although much exaggeration has in all probability crept into the account of the Historian, and although even a question may arise whether the earliest Sovereigns of the Babylonian Monarchy, are to be here understood (for the names are said to have been common to many of the rulers of that Nation,) still it is evident that the assumption was strong that the practice of the Art was of great antiquity, and that Artists had lived who were capable of producing works of extraordinary grandeur; though we have no means of forming any conjecture on the style of the performance, nor of the manner of executing them.[*] Baruch[†] supplies us with some curious particulars respecting the practice of the Babylonians in image-making at a later period of their History; he notices the materials of which their statues were composed, and the manner in which they were dressed, namely, with real drapery, a custom not unusual in early times. The following extracts are interesting, and throw a valuable light on the state of Art in that part of the World at the period at which the Prophet lived. "Now shall ye see in Babylon *Gods of silver*, and of *gold*, and of *wood*, borne upon shoulders, which cause the nations to fear;" "they themselves are *gilded* and *laid over with gold*;" "yet cannot these Gods save themselves from rust and moths, though they *be covered with purple raiment*;" "neither when they were *molten* did they feel it."

About B. C. 630.

Phœnicians.

It is much to be regretted that no monuments remain, at least no monuments of a sufficiently early date, to throw any light upon the style of the Arts of Design amongst the Phœnicians; for the Carthaginian medals or coins which are preserved merely show us the state of Art in a colony established, it is true, by the Phœnicians, but from which we must not venture to judge of the merit, nor of the extent of skill of their ancestors. That they were an ingenious, highly cultivated, and industrious people, there can be no doubt from the evidence we have, and the mention made of them in the earliest classical writers; their Country seems to have been the great magazine of the World, wherein every thing that could administer to luxury and comfort was to be found; they are celebrated as rich merchants, and bold navigators, and their commercial intercourse was extended to all the neighbouring and even to some very remote Nations. Their acknowledged skill, and their establishment of Colonies in all parts, have led many to think that they

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[*] Grævius and Gronov. *Thesaur. Antiq.* and *Dict. de Bayle, ad v. Abraham*, and note.

[†] *Joshua*, ch. xxiv. v. 2. 14, 15. 23.

[‡] *Genesis*, ch. xxxv. v. 4.

[§] Landseer.

[*] Herodotus, who lived about 450 B. C., writes, that there were statues of gold at Babylon; they were of a late date compared with the works to which Diodorus means to refer, but sufficiently early to render their existence important in an historical point of view.

[†] *Baruch*, ch. vi. v. 4. 8. 12. &c.

first taught the Arts of Design in the Countries which they fixed upon as residences; and although we are not disposed to think this entirely the case, there can be little or no doubt that their fame in all curious workmanship was very great. Homer especially distinguishes the Sidonians for their excellence in the Arts of Design, and calls them Σιδόνες πολυδαίδαλοι:[*] in the passage referred to, he is noticing a goblet elaborately worked in silver, and alludes to the artists who executed it. A Tyrian artist, too, was employed upon one of the most celebrated works of antiquity, namely, the Temple of Solomon; we are informed that "King Solomon sent and fetched Hiram out of Tyre, and he came to King Solomon, and wrought all his works; he made the molten sea, with the twelve oxen supporting it, Cherubim," &c. &c.: this was about one thousand years before the Christian Era.

Persians.

It appears that Sculpture was known and practised by the Persians at a very early period of their History, though it is likely that the Art never attained any very great degree of excellence or beauty amongst them; it was in all probability confined to architectural purposes, and the following causes would operate in no slight degree in arresting its progress towards perfection. In the first place the Persians highly disapproved of statues for Religious purposes, that is as objects to be worshipped, because they did not believe, as the Greeks did, that the Gods had the Human form; and we are informed by Diogenes Laertius, and Clemens Alexandrinus, that as they allowed Fire and Water to be the only emblems or representations of the Divine Power, so did they condemn all statues and images whatever; and Xerxes is said even to have destroyed all the Temples of Greece at the instigation of the Magi, because the builders of those edifices impiously presumed to enclose within walls, the Gods to whom all things are open and free, and whose proper Temple is the whole World. Various authorities might be added to these, in proof of the constant war which the Persians carried on against images, and every emblem of Idolatry differing from their own. Another reason for the slow progress of the Art in that Country was the horror they appear to have entertained of all naked figures; and as it would have militated decidedly against popular prejudice or feeling, no Sculptor would dare to represent any figure without its appropriate drapery. Under these circumstances, so unfavourable to the progress and improvement of Sculpture, we cannot be surprised at finding all the figures which have reached us, closely draped, and stiff and awkward, from the ignorance of the artists, who had no opportunity of studying the human form, nor of acquiring that knowledge of its structure which would have enabled them to show the play and variety of the figure under the dress in which they enveloped it. The *bassi rilievi* which have been found amongst the ruins of Persepolis show the general state of Art in Persia at an early period, and will be found to correspond with the character which we have drawn of it. These works bear so strong a resemblance, in many respects, to those of the Egyptians, that they have been thought to be the performances of artists from that Country, carried into Persia, probably, by Cambyses, when he returned thither after having subjugated Egypt; and, certainly, at a later period, the Persians seem to have employed artists to execute their coins who were entirely unacquainted with the improvements which had taken place in Art in the neighbouring States; as may be inferred from the pieces of money, called Darics, of which many, both in gold and silver, are extant, and which exhibit as much poverty in the design and style as ignorance and clumsiness in the execution. Representations of the Human figure, with accessories of a more elevated character of Sculpture, are frequently met with, as the Persian Divinity, Mithras, with his various symbols; but there can be no doubt that these statues and *alti rilievi* are the works of foreigners, Greek or Roman artists, and of a comparatively late period. One proof of this is, that the Persians are said to have sacrificed a horse to this object of their adoration, understood to be typical of the Sun; but in the monuments to which we allude, the victim is a bull, and the place in which the action is being performed is a cave, and we are informed, (in confirmation of our supposition,) that in those parts of Italy in which this worship was introduced, the ceremonies were always carried on under ground, or, in fact, as these Sculptures represent, in caves.

General remarks.

The foregoing general survey of the practice of Sculpture amongst the earliest Nations was necessary to our purpose in giving the History of the Art from the first accounts we have of it; but it has been our endeavour to render it as succinct as was compatible with the subject, being fully sensible that where there are no monuments existing, but little knowledge can be obtained of the styles of Art practised; and that but little light can be thrown on its History, or any peculiarities attending its first introduction, where books of a late date are our only authorities or sources of information. In considering the Arts, and more particularly Sculpture, as it was practised in other Countries, of which it is next proposed to treat, namely, Egypt, parts of Asia Minor, Greece, Italy, and their dependencies, a much more satisfactory field is opened to us; for in each, or nearly so, we shall be able to begin, if not with its birth, at least with its infancy, in point of style, and to trace it progressively to its perfection, decline, and fall. That of Egypt will, perhaps, be the most difficult, as the early History of that most interesting Nation is most lost in obscurity. But as the progress of the Arts, the particular object of the present inquiry, did not keep pace with the improvements of the people in other respects, we shall not have to regret the scantiness of our information on that head so much as might at first be apprehended.

Before we enter upon this part of our History, it may not be improper to observe, that in beginning with the Egyptians, our object is not to derive Sculpture from that, nor any other particular Country, for it does not appear at all necessary that the Art should have been transplanted from one Nation to another, in order to have become so universally practised as it is proved to have been from concurring testimonies and still existing monuments. Migrations of Nations, and the establishment of Colonies from more civilized Countries, would naturally have great influence in introducing improvement in most things; and Religion, customs, and with these the Arts of Design, would, probably, undergo considerable change. But we have undeniable evidence, in our own times, that Sculpture, as well as Painting, have been cultivated in Countries newly-discovered by us, and uninstructed, as far as we can find, by any other People, in these Arts. In Mexico, and the South Sea Islands, as well as in other places, Idols and Pictures have been found, which bear

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[*] *Iliad*, lib. xxiii. v. 743.

undoubted marks of originality, rudely copied from Nature, and to be traced by their symbols, or the subjects they illustrate, to their origin in the tradition of real or pretended exploits of the ancestors of the people who possess them. The Arts of Design, as has before been observed, have owed their birth to necessity and to the desire of commemoration: their cultivation and improvement to pleasure.

The leading styles of Art amongst the Ancients are divided into Egyptian, Etruscan, Greek, and Roman. We may almost say, each of these has its Epochs, and each Epoch its distinguishing character, and in the Greek School each character its author; for we are furnished with the names, peculiarities of style, and, what is still more fortunate, with the works of many of the great masters of Sculpture in that favoured Country, which enable us to judge with tolerable accuracy at what times, as well as under what masters, various interesting changes in the Art took place.

Egyptian Sculpture.

ochs ording to ckel- n.

The History of the Arts of Design in Egypt has afforded a wide field for speculation, but few satisfactory conclusions have been arrived at respecting their origin and earliest practice. Winckelman* ventures to mark three distinct periods or Epochs of Art amongst the Egyptians, making the first include the time that elapsed from their origin in that Country to the reign of Cambyses, in the LXIId Olympiad, or 526 years before the Christian Era. This he distinguishes as the "Ancient Epoch;" "the Middle," according to his classification, embraces the whole period during which Egypt was under the dominion of the Persians and Greeks; and the third or last, which he terms the Style of Imitation, was about the time of Hadrian. In another place, however, the German antiquary seems disposed to fix the commencement of the second Epoch considerably later; namely, at the establishment of the Greeks in that Country, under Alexander the Great and his successors.† The Abbate Fea, the learned editor of the latest edition of Winckelman's Work, endeavours to establish no less than five periods: the first of which lasted from the origin of the Arts in the Country to the time of Sesostris; the second under Sesostris, during twenty-four years of his reign; the third from Sesostris to Psammetichus; the fourth, the period of imitation of Egyptian Art in Rome; and the fifth, that of Theodosius the Great: this classification, and particularly that of the first periods, is too chimerical to be depended upon. A third arrangement of periods of Egyptian Art may be noticed here, by M. Millin, the well-known author of various learned and interesting Works on Art and antiquity; the first is brought down by him to the time of Psammetichus, during whose reign the Greeks were received and treated with favour; the second commenced with the reign of that Prince, and had its duration till the Conquest of Cambyses; when a further change took place by the mixture of the Persian style with the original Art of the Country, marking the third Epoch; which lasted from Cambyses to the reign of Alexander the Great; the fourth was of the time during which the Egyptians were subjected to the Greek Kings, and M. Millin calls the style of this period the Græco-Egyptian; the fifth is the Style of Imitation, and commenced, as in Winckelman's division, with the reign of Hadrian. This classification is more satisfactory than that of the Abbate Fea; but it is a question whether the changes, which the different antiquarians have fancied are to be observed in Egyptian Art, are really sufficiently developed in the monuments which are come down to us, to allow of our making such distinctions. The most objectionable part of these divisions seems to us to be the fixing changes so early as those adopted by Fea and Millin;* for although Cambyses endeavoured to abolish the customs and even the Religion of the Egyptians, we are not informed that he made any changes in the Arts, or in the treatment of artists; and it is but fair to believe that had he entertained such a wish, the Persians had no Art which they could substitute superior to that which they found in the Country they had subdued. It is important too, while considering this subject, to bear in mind that the changes that Cambyses wished to effect, and perhaps did partially effect, were of no great duration, as we are informed† that his successor, Darius, permitted the Egyptians to return to their own usages; and it is remarkable, and offers some confirmation of this position, that Plato, who lived about 120 years after Cambyses, speaks of the attachment which the Egyptians cherished for all their most ancient customs, observing, that no change had taken place for Ages.‡ Under these circumstances, we should be disposed to consider the second opinion of Winckelman as the most satisfactory; namely, that the first style of Art, such as it was practised in the earliest times, lasted with but slight variations until the general introduction of Greeks during the reign of Alexander the Great, when a change took place in most of the institutions of the Country, and the Arts of Design, naturally enough, underwent some alteration from the introduction of the purer taste of the conquerors. But it will be remarked, that the characteristics of Egyptian Art are peculiarly its own; and although some general resemblance to it may be found in some stiff and hard first efforts in other Countries, and although, in the course of Ages, the practice may have been influenced, in minor details, by correspondence with foreigners, sufficiently perhaps to enable careful observers to distinguish the variations of the periods alluded to, yet the leading character of all Art in that Country remains the same; and whether it be of the most remote period, or of the Ptolemies, or of the time of Hadrian, it bears a style or manner which alike stamps it as Egyptian.

B. C. 330. and sub.

Causes of slow progress in Egypt.

It excites our astonishment that a Nation so distinguished, so superior indeed to other Nations in Science, should have made so little progress in the Arts of Design; for we cannot but be struck by the fact that their improvement in them, and especially their imitation of the Human figure, did not keep pace with their advancement in other respects. In the Arts of Design, though their works were surprising and magnificent from their scale, they seemed destined never to arrive at perfection; and it becomes an inquiry of interest to endeavour to

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* Winckelman, *St. delle Arti del Disegno*, lib. ii. c. 1.

† Ibid. *Opere inedite*, *Trat. Prel.* ch. ii.

* We have thought it right to notice the opinions of the above ingenious writers, but the reader who desires to enter more particularly into the subject of Egyptian Art and antiquity is referred to the works of Zoega, Hamilton, Bankes, and especially the late researches of Young and Champollion.

† Diod. Siculus.

‡ Plat. *De Leg.* ch. ii.

discover an adequate cause for this failure. One of the principal reasons which has been adduced is the absence of beautiful forms amongst the Egyptians, either in face or figure. Ælian observes that, in his time, it was rare to find a well-made or beautiful woman; and another writer* says of them, *Homines autem Ægyptis plerique subfusculi sunt et atrati, magisque mæstiores, gracilenti et aridi*, &c. It is well known that they had no public Games, like the Greeks and Romans, for the exercise of their bodies, by which their artists could have the opportunity of studying the actions and variety of the figure; causes sufficiently powerful to prevent their imitative works possessing much excellence of form. The artists too, it must be remembered, were altogether precluded from studying Anatomy, so essential to the perfection of the Fine Arts and of Sculpture especially, by the extreme respect, approaching to veneration, that was paid to the dead. So jealous were they of any indignity being shown to the bodies of the deceased, that they considered the common and necessary offices which were performed as having something revolting in them; and, consequently, the persons appointed by law to embalm the dead and prepare them for interment were looked upon with horror and detestation, and were obliged to seek safety by flight from the indignation and excited feelings of the surviving relatives. The next cause that may be assigned for the little progress that was made in the Arts, was the strong and unconquerable attachment they had for all their most ancient customs; which has led some writers to suppose that the artists were forbidden to depart from established rules applied to the representation of the human figure. From the comparative skill which they have evinced in executing animals, it seems more than probable that it was in these inferior objects alone that they were permitted to exercise their own judgment or skill; while statues or pictures of men and women, appropriated to purposes of Religion, and confined to the representation of Divinities, Kings, and Priests,† were not to be elevated at the will of the artist beyond the character left by the Ancients, and, therefore, established as by Law. We must also notice another influential cause, the division of the people into castes or professions, which obliged a son to follow the trade or calling of his father, whatever it might be;‡ by the same rule it was prohibited for any person, however decided his disposition for them might be, to practise the Arts of Design, unless he had an hereditary right so to apply his talents. One more cause for the slow progress of the Arts in Egypt—more influential perhaps than any other in a profession which requires for its consummation and perfection much nursing and protection—was the little esteem in which artists were held in the Country; they were classed in the lowest rank, and neither had opportunty nor permission to rise above it. Thus their practice was merely mechanical, unaided and unenlightened by the mind or sentiment which a student, who feels he may arrive at distinction by excelling in the higher branches of his Art, would endeavour to throw into his works. The statues and *bassi rilievi* remaining, even at the present day, are almost without number; and wherever ruins have been discovered, whether of Temples, Tombs, or Obelisks, there also have Sculptures or Paintings been found. The continual practice, therefore, which such a vast quantity of work afforded must, under any other circumstances, have occasioned improvement; and were it not for the paralyzing influence of the causes above enumerated, we should be utterly at a loss to comprehend how it was possible, in a Country where Art was so extensively cultivated, that it should have remained so stationary in point of style.

The general characteristics of Egyptian Sculpture are extreme simplicity or uniformity in the composition of the lines, want of variety of action, and the absence of sentiment or expression in the heads. Their statues are standing quite upright, or sitting with all the limbs at right angles to the body, or kneeling on both knees; the arms are generally attached to the body, the hands close to the thighs, though in female figures one hand is frequently placed across the breast; in the kneeling figures, the hands are brought a little forward on the front of the thighs, and support a box containing idols; the backs are uniformly supported by a sort of block or pilaster, which is generally covered with hieroglyphics; the feet are for the most part parallel and joined together, though this is not always the case, for in standing figures one foot is sometimes slightly advanced before the other. The statues of men are entirely naked, excepting that a sort of apron is folded across the loins; those of females were dressed in one long and simple garment, fitted close to the body; there are no folds in it, and it is only to be distinguished from the figure by a slightly raised border at the neck and feet; the form of the breasts is sometimes indicated by their natural projection being circumscribed by an indented line. It has been remarked, and with great justice, that the Egyptians appear to have paid great regard to decency, and have preserved more modesty in their figures than any other people who have practised the Arts; occasionally, works of a different character are met with, but they may always be fairly attributed to a late period. The heads, when they are human, are sometimes uncovered, but more frequently they are surmounted either by an emblematical head-dress, in which is distinguished the lotus, a globe, a serpent, or some sacred symbol, or that more generally found in representations of the human figure in Egypt consisting, as is well known, of a sort of close cap or head-piece, entirely concealing the hair and falling in broad flaps upon the shoulders. The foregoing observations are principally applicable to their statues; but the Egyptians also worked a great deal in *basso-rilievo*, as almost all the Tombs and Temples which have been discovered are richly decorated with Sculpture of this sort. They do not of course differ very materially from the statues as far as regards general character, but they are somewhat varied in treatment. It will be found that there is frequently greater attention paid to details of costume, as in expressing more folds, and a bolder attempt at action is observable in them, as if the artists were not so strictly confined in their works in this style as in statues. This is particularly striking in some *bassi rilievi* on one of the great Temples at Thebes. The principal of them represents a battle, or the exploits of some hero who is destroying his enemies; he is made of colossal proportions compared with the other figures in the scene, and there is an attempt at composition, and even beauty of form, in the heads of some of the combatants, which offers ground for curious speculation as to the period at which the work

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* Ammianus Marcellinus.

† Herodot. lib. ii.

‡ Diod. Sic.

was executed, and the subject to which it relates. We shall here point out a peculiarity in the execution of some of the Egyptian *bassi rilievi* still preserved to us. A ground was sunk below the face of the stone to be employed, preserving, however, a margin of the original face all round; the figure or subject to be represented was then worked within this, so that there was no relief or salient part beyond the original plane, which formed as it were a protecting frame round it. It may be observed too, that it was by no means uncommon amongst this people to paint their *bassi rilievi*, and indeed their Sculpture in general; as has been ascertained by the discovery of works either accidentally buried or enclosed in Tombs; on which, from the atmosphere having had no influence in decomposing them, the colours have been found as vivid as when first applied. Although the additional splendour of effect obtained by it for decorative works, was probably the principal cause for introducing Painting upon their Sculpture, other and considerable advantages were also gained by its adoption: first, the Sculpture was longer preserved, from its surface being so defended; and next, their works, by the union of the two Arts, became much more complete, as the artists were enabled to add many details by painting them which were altogether omitted in the Sculpture: it will be seen, however, that painting statues and works in Sculpture was not confined to the Egyptians, but was general in other Countries.

The above remarks apply to the *general* characteristics of Art in Egypt; before we dismiss this part of our subject, we shall point out some of the peculiarities which are offered us in the details of their works, and of which the interesting specimens preserved in England, particularly those which have been added within a few years to the collection of Sculpture in the British Museum, afford us numerous and highly valuable examples. In the first place, the form of the face is rather short or round, the eye, large and pointed at the extremities, has a slight inclination upwards at the outer corner; it is not sunk into the head, as is observable in Greek Sculpture, but projects as far forward as the brow, which is merely indicated by a slightly raised line or sharp edge; the nose is much rounded at the point, somewhat flattened, and rather wide at the nostrils; the projection of the cheek-bones is considerably marked, but with great roundness, and this it is which gives the fulness to the upper part of the face; the character of the mouth is peculiar, the lips are heavy or thick, and slightly turned up at the corners, casting a simpering or silly expression over the countenance; the mouth too is always represented closed, differing in this respect from the early works of Greece and other Countries, where we find the mouth generally, if not always, slightly opened; the chin is rather small, and without that projection which gives so much beauty to the face, especially in the profile view of it; in the placing of the ear there is also a remarkable peculiarity in Egyptian statues, it being situated so high up that in many instances the lobe or lower part of it ranges nearly in a line with the eyes. The hands and feet of their figures are long and flat, the nails are rudely marked, but there are no indications of knuckles nor joints, which gives, even to the most highly finished and best preserved works, the effect of having had the extremities worn or smoothed down; the toes are rather long, and the smaller one, instead of being turned or bent, as in Greek statues, is extended, and has the same pressure on the ground as the others. It has been observed in some statues, which are represented standing, that the feet are not of equal length; one is generally a little advanced before the other, and the hindermost, on which the figure rests, is made the longest; the navel, in figures of both sexes, is strongly indicated.

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We wish in the foregoing observations to be understood as speaking of works distinctly Egyptian, applying that signification to the style of monuments believed to belong to their first or ancient period, as Winckelman has denominated it; original and unmixed with any of the styles of the more enlightened people—(enlightened with regard to their taste and knowledge in the Fine Arts)—who subsequently gained power in the Country.

Materials.

The Egyptians used a variety of materials for the purposes of Sculpture; we find works in wood, baked clay, some few in ivory, in metal, in a variety of marbles, in basalt, granite, alabaster, a sort of sandstone, serpentine, &c.; for their colossal works they employed the sandstone, basalt, porphyry, and granite; and Herodotus says, that at Sais and Thebes there were also colossal statues in wood.* There are none of large dimensions in bronze; the works in the other materials are for the most part very small, having the appearance of Lares or household Gods, either under the human form or that of animals.

The clean execution and exceedingly fine surface so remarkable in Egyptian Sculpture has excited the attention of the curious; and it leads to the belief that their knowledge in hardening metals must have been very far beyond ours, to have enabled them to produce such carefully finished works in materials which almost defy our best-tempered instruments. It is a remarkable fact, that when the colossal head, called that of the Young Memnon, was placed in the British Museum, and it was found necessary to make some holes in it for the insertion of irons to join two of the pieces together, the hardness of the granite was so great that six or eight blows rendered the tools employed perfectly useless.

Etruscan Sculpture.

Etruscan.

The next School of Sculpture which offers itself to our notice is the Etruscan. Its early History, its origin as a School of Art, and the Nation from which it was derived, have afforded subject for much discussion amongst antiquaries; but nothing very satisfactory has been adduced by which we can form any decided opinion upon it previously to the emigrations by which the Greeks obtained an establishment in Etruria. It is not intended here to question the possibility, or rather the probability,† that there was some original Art in Etruria before the arrival of the Greek colonists; some of the monuments, indeed, which have come down to us have been produced as instances of original works of an extremely early date They bear no allusion to the Greek fables or mythology, consisting of figures of men, of Genii with and without wings, ceremonies, &c.; but in the greater part of those that have reached us there is such strong evidence of Greek origin, (in their subjects rather than in any distinguishing style of Art,) that we are justified in considering them as drawn from Greece. We

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* Herod. lib. ii.

† Niebuhr, *History of Rome*, vol. i.

would, however, here observe, that the works of ancient Greece and of the Etruscans have been frequently confounded from the similarity of their style alone; but it must be remembered that this style is nothing more than the general characteristic of all Art in its infancy, the same in Greece, in Etruria, as in all other Countries; or, as it has been observed from the learned Lanzi, in speaking of the conjecture that the Art of the Etruscans was brought from Egypt originally, *La supposizione che gli Etruschi traessero dagli Egizj le loro Arti e il loro disegno è priva di fondamento, poichè come avvertì il Lanzi, la rigidezza e il rettilineo dei segni non hanno bisogno di venirci dal Nilo, e nei principj delle Arti presso tutte le Nazione si vede lo stesso carattere* essendo quello stile non tanto Arte, quanto mancanza di Arte.[*] These observations, however, are only intended to apply to the earliest works, in which the mere similar rudeness of execution has been erroneously considered a corresponding style of School. Strabo[†] has a passage in which the resemblance of the works of the Egyptians to those of the Etruscans (or Tyrrhenians) and the early Greeks, is in like manner noticed; but we certainly are not led to infer from it that there was any communication of first principles between the three Nations. A distinction, as Lanzi observes,[‡] must be made between the Etruscan style and works executed by Etruscan artists, which will be found on examination to be very necessary to enable us to comprehend and judge of the productions of this School. The "Etruscan style" was a peculiar manner of treating Art, which was retained by those attached to this School from its foundation down to a very late period; it was particularly distinguished by the Latins, and called by them *Tuscanicus;* it was applied exclusively to Art, and always signified a *style*, and its practice was not necessarily confined to natives of Etruria. All works executed in the hard and dry manner peculiar to this School, were, therefore, called *opera Tuscanica.* A passage from Quinctilian will illustrate still more strongly the application of this style, where he is speaking of the works of some of the most celebrated Greek Sculptors: *Duriora et* Tuscanicis proxima *Callon et Egesias; jam minus rigida Calamis; molliora adhuc supradictis Myron fecit.*[§]

Connection with the Greek style.

Some difference of opinion has arisen respecting the dates of the various migrations of the Greeks, but the earliest, generally believed to have taken place about fourteen centuries before the Christian Era, was that of the Pelasgi, or as they are also called, Tyrrhenians.[||] Subsequently, about 600 years after the first, another very considerable colonization of Greeks took place;[¶] and to this much of the improvement of the inhabitants of Etruria in the Arts of Design is attributed. It is moreover extremely probable that the Arts were practised to a great extent in that Country, where for a long period they were enjoying repose, while in Greece, from a variety of causes, (amongst which may be particularly noticed their internal and external divisions and wars,) they were neglected and most probably suffered to fall to decay. The various representations of subjects from the Greek History and Fables, found in Etruria, and supposed to have been executed at a period when there was no Art in Greece, have been adduced in support of this opinion; amongst them may be particularly noticed the celebrated Gem formerly in the collection of the Baron Stosch, representing five of the seven Chiefs who conducted the expedition against Thebes; a remarkable event in the early History of Greece, and of which there is no equally early representation found amongst the works of the Greeks themselves. If this Gem be indeed of the high antiquity ascribed to it, it offers a remarkable confirmation, we think, of the Etruscans having practised the Arts when they were neglected in Greece; but we are aware that its antiquity has been questioned, and its execution attributed by one writer[*] to so low a date as subsequent to the Vth century of Rome. Judging however, generally, from the monuments of Etruscan Art which have come down to our time, they may be fairly considered as derived from the Greek School; not, as we have before stated, from any distinguishing style, but from the subjects chosen for illustration; other works may have existed, perhaps do now exist, which may have been executed by the original inhabitants of the Country, but the monuments that we have naturally lead to such a conclusion.

Characteristics.

With respect to the characteristics of the style of Etruscan Art, it will be observed that a certain variety exists: in some of their works the forms are undefined, the hair and drapery stringy, and arranged with the utmost regularity and stiffness;—in others there is a studied affectation of execution, with an exaggerated and forced action of parts even to the fingers, the ends of which are turned up in the most unnatural manner; but with this difference in execution one peculiarity will be found to pervade all the works of the School, namely, a general absence of grace and character. Unlike the Greeks, they do not appear to have founded their practice on Nature, and the consequence is a want of beauty and appropriate expression or sentiment in their works. It will also be observed that the Etruscan artists continued, long after they had had opportunities of improving themselves in that respect, to execute in the same hard, dry, severe manner, by which, in other Countries, only the earliest works are characterised: Winckelman[†] has adduced reasons for this fault, but they do not appear sufficient to account for the almost Egyptian pertinacity displayed by the Etruscan artists, in following the model of style which their precursors left them. That they had vast practice in the Arts, and particularly in Sculpture, may be inferred from the quantity of works of

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[*] Cicognara, *Stor. della Scult.* vol. i.

[†] Strabo, lib. xvii.

[‡] Lanzi, *Notizie sulla Scultura.*

[§] Lib. xii.

[||] It is not necessary here to enter into an inquiry of the particular distinction between the Pelasgi and the Tyrrhenians, though it is probable that the terms have been used indiscriminately by those who have spoken of these colonies. A variety of Works may be consulted on the subject; amongst them those of Raoul Rochette, *sur les Colonies Grecs;* Clavier, *sur les Premiers Temps de la Grèce;* Lanzi, Winckelman, Niebuhr, &c. &c. It appears probable too, that other Greeks came over and settled amongst the Etruscans during the long interval between the two principal emigrations.

[¶] Herodotus. Thucid. Plut. Strab. lib. v.

[*] *Dissert. di* P. Antonioli. Stosch, *Pierr. Grav.* Winckelman, &c.

[†] Winckelman, lib. iii. It is worthy of remark that the Etruscans, like the Egyptians, had a powerful hierarchy, for their chiefs, "Lucumones," were Priests as well as Governors, and they may have exercised an influence in preserving the forms once consecrated by Religion from profane innovation. That this prejudiee, if it did exist, was not so strong as that which was submitted to in Egypt, is evident from some varieties in the Etruscan work, but it may have operated to some extent in checking the progress of style.

pture.

various kinds that have been found in their Country, as well as from the accounts of some of the ancient writers;[*] if the statue of Romulus was of his time, as was pretended, it must have been by Etruscan artists. We read too of their efforts in the plastic Art, in a statue of Jupiter of clay, which was painted red, also of a Hercules in the same material; and it is said that when, after having sustained many long and troublesome wars against the Romans, they were finally subdued by that people, and became a Roman Province, (which event happened about two hundred and eighty years before the Christian Era,) so many as two thousand statues were taken from Volsinium alone![†]

Grecian Sculpture.

The Art of Sculpture, though every where of equal importance, perhaps, in an antiquarian point of view, does not afford us the same interest, nor excite the same feelings, when we are examining its practice in other Countries, as it does in Greece and its colonies. The associations connected with that Country, added to the peculiar excellence which the Arts of Design, and particularly Sculpture, attained there, are sufficient to account for this difference; and we cannot but feel that the real History of Art, as a refined and intellectual pursuit, can only be known by tracing its progress amongst that favoured and gifted people; by whom, in a few centuries, it was carried to such wonderful perfection. In other Countries in which Sculpture was practised, it seemed destined never to go beyond certain limits, and if it did sometimes rise superior to the rudeness of first attempts at form, still it never attained strength sufficient to step beyond a wretched mediocrity. Mere representations of objects were produced, unelevated by the introduction of sentiment or feeling. It was in Greece alone that the advance of the Fine Arts, and particularly of Sculpture, was progressive towards perfection; it was here that it rose superior, and became something beyond a mere mechanical pursuit; it was here that Mind was made to illumine Matter, and that the conceptions of rich and glowing fancies were embodied in the productions of their artists.

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The extraordinary superiority of the Greeks in this respect over all other nations, a superiority so decided and so universally admitted, that the terms Greek and perfection are, as applied to works of Art, almost synonymous, is a phenomenon which has engaged general attention, and has been attempted to be accounted for in various ways, morally and physically. But no sufficient reason has yet been assigned, we think, for an excellence which, even amongst them, was partial, and confined to some States or particular parts of the Country. By some writers, the great excellence of the Greeks in the pursuits under our consideration has been attributed to the fineness of climate which they enjoyed; but it requires no argument to show that such a cause is inadequate to produce such extraordinary effects; other Countries have had equal advantages in this respect where the Arts have comparatively had no existence. An ingenious author[*] has even gone so far as to assert, on the authority of ancient writers, that the climate of Greece, generally, was very unequal, that they were often visited by fogs, that the cold of winter was in many parts extremely rigorous, and the heat of summer excessive, and that in Attica, especially about Athens, they were afflicted by a peculiar and annoying wind; and although, in some spots, vegetation flourished in the greatest luxuriance, that in others the earth was perfectly naked. It is not, however, intended here to prove that the climate of Greece was bad, but merely to observe that it had its inconveniences, and to reply to those who are disposed to attribute an all powerful influence to climate alone. By some again it has been supposed that the beauty of form of the people amongst whom the Arts were practised, affords a sufficiently powerful reason for the success which attended them; but we do not conceive that that circumstance would have all the influence which its supporters would derive from it; besides, we are not told that the people who most excelled in the Fine Arts, (namely the Athenians,) were the handsomest of the Grecians. Cicero,[†] speaking of the youths he saw at Athens, says he observed few who were really handsome; and although we will not infer from this that they were none of them so, especially when we have the names of so many handed down to us as celebrated for this quality, yet we may fairly conclude that the Fine Arts owed their superiority in Athens to some other cause than the universality of beautiful forms. We would remark too at this place, and it is a curious circumstance, that those women especially whose celebrity for beauty has reached us, were none of them natives of Attica, the State in which Sculpture most flourished. Phryne, for instance, was of Thebes, Glycera of Thespiæ, Aspasia of Miletus, and the masterpiece of Xeuxis was an union or combination of all the beauties afforded by the study of seven virgins of Crotona. The admiration of beauty amongst the Lacedæmonians is well attested,[‡] but the Fine Arts were proscribed at Sparta. Neither does a peculiar form of Government afford a sufficient reason for their success; for we find they flourished where there were essential differences in this respect. They were not fostered in the most powerful States, as may be inferred from the circumstance of Sicyon, the feeble Sicyon, holding, together with Athens, the first rank in the cities of Art, whilst the rich and magnificent Corinth was only of secondary consideration in this respect. In fact, if wealth, pomp, and luxury had been necessary to their developement and success, it is natural to believe that Asia, and not Greece, would have been the seat in which the Arts would have established themselves.

Grecian.

Perception of Beauty.

Thus it does not appear that the aptitude (if we may be allowed the term) of the Greeks for the Fine Arts depended upon those circumstances to which their success has been so generally attributed, and upon which, however useful and important they may have been as assistants, too much stress has been laid; it must therefore be sought for elsewhere, and we are led to think it arose out of the particular constitution of the people; principally it may have been owing to the love of simplicity which for a long period was so general

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[*] Plin. *Nat. Hist.*

[†] Ibid. lib. xxxiv. c. 7.

[*] M. Emeric David, *Essai, &c.*

[†] *Quotus enim quisque formosus est? Athenis cùm essem e grege epheborum vix singuli reperiebantur. De Nat. Deor.* lib. ii. c. 79.

[‡] Ælian. *Var. Hist.* lib. xiv. c. 27. Athen. lib. xii. c. 2.

amongst them, and which seems to have pervaded their language, and even to have extended to their actions and their feelings, united to a quickness of perception and admiration of that which is admitted to constitute Beauty, possessed by them beyond any other people, and which influenced them in all they did. The artists in their choice, as well as their treatment of subjects, seem to have been careful never to lose sight of this principle, nor to express any passion or feeling so violently as to be at variance with the laws of Beauty, united with simplicity; and as *extreme* expression would have interfered with its existence, it will be found that the Ancients studiously avoided it in their works. Laughing or crying figures can have the effect of being so excited but for a moment, afterwards the expression is but grimace, as may be seen in many productions of the later schools of Sculpture. In all the varieties which have come within the scope of their practice, even in subjects of the greatest excitement, from the convulsive struggles of a Laocoon to the equally intense but quiet suffering of the Dying Gladiator,* this solicitude will be observed. It is true a restraint was sometimes put upon them by their Religion, which obliged them to represent their Deities according to rule, founded on ancient and established usage or popular belief; or to accompany them with attributes destructive to, or at least materially affecting, that beauty and simplicity which constitutes the charm of Art; but in prescriptive works, for to such the last observations are intended to apply, we are not to look for the real feeling of the artist, and it is only when unfettered by restraint that even the Greek could act up to the impulse of his mind, and follow that Beauty which filled his imagination, and which was the first and favourite object of his pursuit. A further proof of the attention which the Ancients paid to Beauty in works of Art, applying equally to the choice of subjects and to the manner of treating them, is the contempt and derision to which those were exposed who confined themselves to representing common or inferior objects. We are told that an artist named Pyreicus,† who painted barbers' shops, and such trifling subjects, with all the care of one of the Flemish School, got the nickname of *Rhyparographus;* and it is said that the Thebans had a law which applied particularly to artists, who were subjected to a fine if the works they executed fell short in beauty of the objects they professed to imitate. In Greece, personal beauty was considered to confer a title to distinction, and the estimation gained by its possession is everywhere attested by ancient writers. We are informed, that the Priests of the young Jupiter at Egea, those of the Ismenian Apollo, and those of Mercury at Tanagra, were youths to whom a prize of beauty had been awarded.‡

Advantages derived from Public Games.

Though we have observed, that the natural constitution of the Greeks was particularly favourable to the success of the Fine Arts, we must not omit to notice, at the same time, that they were assisted by a variety of other circumstances highly propitious to their advancement, and which did not exist to the same extent in any other Country. Principally, then, the public Games and combats, in which the competitors were for the most part naked, offered great advantages to the artists of Greece, and were of vast assistance in enabling them to carry Sculpture to perfection. The value put upon distinction in these exercises, for which the most exalted characters of the Country were ambitious of contending, and the honour that was conferred even upon a City or State, by merely having given birth to a victor in the Games, rendered the education of their youth a subject of the first importance and interest. The Gymnasia or Schools in which they were trained were the resort of men of rank and talent. Personages of the highest consideration in the State, as well as Philosophers, Poets, and Artists, were in the constant habit of attending them, and were thus accustomed to the contemplation and study of the human form in all its varieties, whether in repose or in action; they became well acquainted with the beauty and with the capabilities of the human figure, and, consequently, fair and competent judges of imitative Art. But the Sculptor especially benefited by these establishments, from the intimate knowledge he acquired of the formation, as well as the active powers of the figure. The causes of the superiority of the conqueror in the race or wrestling-match were diligently sought after, and the properties discovered most generally to exist in those who excelled in the various exercises, were presumed to be best adapted for the purposes required, and were therefore adopted by him into all representations of the human figure in which the character demanded these qualifications. The wide shoulders, for instance, and spacious chest of the brawny wrestler offered to the Sculptor the properties essential for the statues of Hercules, and others of that class in which physical strength was to be portrayed; the clean legs and light proportions of the victor in the race, gave the character of the messenger of the Gods; and the union and judicious combinations of strength and agility afforded the characteristics of the general athlete, or, modified into all their varieties, produced that Beauty, called *ideal,* which peculiarly distinguishes their sublimer productions, and their statues of Demigods and Heroes. By these means, that pervading harmony, the natural and unfailing result of propriety, was attained, which gives so peculiar a charm to almost all the works of the Grecian School, without which no production, however beautiful it may be in detail, can ever please. It must be remembered too, before we leave the subject of the Public Games, that, in witnessing them, nothing (during the best times of Greece) was ever presented to the spectators that was capable of doing violence to the finer feelings; no barbarity disgraced these amusements; for the introduction of the disgusting exhibitions of Gladiators and the fights with wild beasts were reserved for a later period. It was highly conducive also to the advancement of Sculpture that statues were erected to those who excelled in agility and strength of body; and the greatest distinction that could be conferred, (an honour only permitted to those who had conquered a certain number of times,) was the right of dedicating an Iconic (or Portrait) Statue, which was erected in the most sacred place for such a purpose, the Altis, or Sacred Grove, near the Temple of the Olympian Jupiter; to be seen and admired by the crowds who

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* It may be objected here that these works are of a later date than the finest Greek productions; this is still a question, and it is immaterial, as the principle of which we are speaking exists in so remarkable a degree in them, that they fully merit the distinction of being so noticed, whether the learned agree in allowing them to be really Greek or not.

† Plin. *Nat. Hist.* lib. xxx. c. 37.

‡ Pausanias, lib. vii. and ix.

Early Sculptors.

Dædalus.

The first Sculptor who gained sufficient celebrity to have his name handed down to posterity is Dædalus; his era, however, is so remote, and the statements respecting his adventures and discoveries in Sculpture, as well as the more mechanical Arts, so mixed up with the marvellous, that it may be justly questioned how far any of them are worthy of credit; and as Dædalus was in all probability a distinguishing name given in the Ages of antiquity to all artists who had produced any work out of the common way, it is easy to conceive how the inventions and improvements of many became, in subsequent times, attributed to one. As some account has already been given of Dædalus in the BIOGRAPHY OF THE EARLY SCULPTORS OF GREECE in a former part of this Work, it is unnecessary to dwell in this place upon his history or productions. There were, however, several Sculptors of the same name, and the Athenian has in some instances been confounded with a Dædalus of Sicyon, who lived nearly 700 years later. As the style of Art of this more modern Dædalus would not, it is conceived, be very dissimilar to that attributed to works of a much earlier time, the productions of this Sculptor might easily have elicited the remarks which Pausanias and others have made upon them, under the impression that they were works of a still more remote antiquity.

Smilis.

The next Sculptor who occurs in the annals of Grecian Art, after Dædalus, is Smilis,[*] or Scelmis, a native of Ægina, and son of Euclides; he was said to be contemporary with Dædalus, and was considered the author of a statue of Juno, at Samos, and which, according to some traditions, had been brought from Argos by the Argonauts who dedicated the Temple; a circumstance which has occasioned the antiquity of Smilis to be doubted, the Argonauts not having visited Samos till very long after the time at which Smilis is said to have lived. This, however, is not sufficient to affect the antiquity of the work, for the Argonauts might have brought an *ancient* statue with them; the circumstance of its being composed of gold and ivory has much more weight in leading us to attribute a later date both to the statue and to the artist who executed it.

Endœus.

Endœus,[†] a native of Athens, was a scholar of Dædalus, and is said to have followed his master to Crete, when he fled to that Country after the murder of his nephew Talus. He appears to have been very extensively employed, and amongst other works Pausanias particularly mentions a statue of Minerva in wood, of colossal dimensions; he is also said to have executed others in marble and ivory, but there is every reason to believe that many of the works attributed to this Sculptor are of a much later date. The author of the observations prefixed to the valuable Work on Ancient Sculpture published by the Society of Dilettanti, in 1809, remarks, that a head of Minerva on a silver tetradrachm of Athens, which is engraved in that publication, is probably copied from the above figure of Minerva by Endœus, it being by far the most Archaic of the heads of that Goddess observable on Athenian Coins. This learned Writer thinks that the Sculpture in *alto rilievo* over the gates of Mycenæ, representing two lions rampant against a sort of pillar or column, is the most ancient specimen of the Art extant; it is still in the situation in which it was originally placed, being built in with, and forming part of the walls, and on that account, as well as from the interest it possesses as a specimen of very early Sculpture, has great claims upon our regard.

Grecian Archaic.

The chain of Sculptors in Greece is here interrupted, (and the existence of the last mentioned is even doubted by some,) owing to our imperfect information, or, as is more probable, to the invasion of the Dorians on the return of the Heraclidæ, comparatively a more barbarous race, to Peloponnesus. It appears that the Arts were now practised with success deserving notice by a distant people; for we find that the next Sculptors who are recorded are the Telchinians of Rhodes,[*] who seem for many years to have enjoyed a high reputation in Sculpture; but no monuments of any description remain of this people, or of that time, by which any estimate can be formed of the merit of their productions; it is impossible, therefore, to offer any account of their style or of the character of their works. The next best accredited remains of Grecian Art are Coins; and although it is extremely probable that the general Sculpture of different Countries varied from and had improved upon the stamps used for money, (which as an established and well-known device were most likely preserved for the sake of convenience or policy,) yet, in the absence of other monuments, we must be content to seek information from them. In those extant of the earliest period in which the human head is exhibited, the eye has a very remarkable character, being represented large, and in the *front* view, while the rest of the face is in profile; in other respects, and wherever the whole figure is introduced, the style was energetic, the execution turgid, and corresponding very nearly with the description which has been already given of Archaic Art. It would be extremely difficult, perhaps impossible, to explain in a satisfactory manner to the reader the slight variations in style and treatment which took place in Coins as knowledge in Art advanced; the Coins themselves should be studied, the best engravings of them generally failing to give the details so essential to the right understanding of works of this minute description.

Early Coins.

Plate I. Fig. 2.

Phido. B. C. 869.

Phido of Argos is said to have struck the first money in Greece in the Island of Ægina, about 869 B. C., and there are some Coins of that Island extant, which, from the rudeness of the Sculpture, and the imperfect execution, are considered to be of nearly as early a date; but it must be confessed that they throw but little light upon the state of Art of the period to which they are attributed, their device being merely a tortoise. The employment of metal in Sculpture probably took place soon after the striking of money under Phido, and we, therefore, find that Gitiadas,[†] the next Sculptor whose name is recorded, made various statues in brass. Gitiadas was a native of Sparta, and exercised, as was frequently the case, the two professions of

Gitiadas. B. C. 740.

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[*] Paus. lib. vii. c. 4.

[†] Ibid. lib. i. c. 26. and lib. vii. c. 5.

[*] Winckelman, *Storia delle Arte di Disegno*, ix. l. *Prelim. Dissert. Dillet.*

[†] The dates of Gitiadas and Learchus are by no means ascertained. The former is placed thus early on the strength of a passage in Pausanias, which makes his date, it is conceived, quite independent of the Æginetan Sculptor, with whom he has usually been considered contemporary. Learchus should follow Dipœnus and Scyllis, (if their date be, as we suppose, above 700 B. C.) but we have noticed him here as a distinguished artist in the early History of Sculpture in metal, and unconnected with any other Sculptors; if he were the Scholar of Dipœnus and Scyllis, they must have flourished much earlier than Pliny says; the reason will be obvious if the reader will consult Pausanias.

earchus.

Sculpture and Architecture; the period at which he lived is not precisely ascertained, but there is reason to believe that he was flourishing about the time of the first Messenian War, or about 740 years before the Christian Era; there were works remaining at Lacedæmon in the time of Pausanias, which were attributed to this artist.[*] Pausanias also mentions having seen at Lacedæmon, a brass statue of Jupiter by Learchus, a Sculptor of Rhegium, which, he says, was the most ancient statue known in that material; this has led to the inference that the Arts were in a more advanced state in Italy at that time than in Greece; and judging from some Coins which remain, it has been thought that the state of Art in all the Colonies was more flourishing at this early period, namely, the VIIIth century before Christ, than in the Mother Country. It must be acknowledged that there are many inconsistencies in the accounts we have of Learchus, and chronologers and antiquaries have differed considerably in deciding upon his date; but there can be no doubt that he lived at a very remote period, certainly not very much later than he is here placed.

elecles.
hœcus.
heodorus.
ibutades.

Passing over names of minor importance, we arrive at Telecles, Rhœcus, and Theodorus, who appear to have introduced great improvements into the practice of Sculpture; their dates are of considerable importance in the History of the Art, as they have been thought early enough to have been the inventors of various branches of it. Pausanias says, they first cast brass statues; and tradition, according to Pliny,[†] attributed to them the invention of the plastic Art, though the Corinthians claimed the distinction for Dibutades: at what time Dibutades lived is uncertain; he was a Sicyonian by birth, and exercised the trade of a potter at Corinth, but, as we have before observed, so simple a discovery as modelling figures in clay was, in all probability, made in the earliest stage of Society, and is not to be attributed to any one in particular. Rhœcus and Theodorus are mentioned by Herodotus, Pliny, and Pausanias; Rhœcus is said by Herodotus[‡] to have built the Temple of Juno, at Samos; he was also the author of a statue of Night in the Temple of the Ephesian Diana;[§] Pausanias says, that he was unable to find any of the productions of Theodorus; but Herodotus, and, subsequently, Pliny, allude to works by a Sculptor of that name. As there were at least two so called, who were living about the same time, some confusion may very easily have arisen amongst the Ancients in speaking of them; one, we are told, was a son of Rhœcus, another of Telecles. According to Herodotus, Theodorus engraved the celebrated ring of Polycrates, Tyrant of Samos, so remarkable in History for the good fortune which always attended him; he also made one of the magnificent vases which Crœsus, King of Lydia, presented to the Temple at Delphi. Pliny records a remarkable instance of minute execution by Theodorus; he says, he cast a brass statue of himself, holding in one hand a file, in allusion, probably, to his profession; and in the other a *quadriga*, so small that a fly could cover it with its wings. Great difficulties occur in fixing the dates of these artists; Pliny says, they lived long before the expulsion of the Bacchiadæ from Corinth; an event which took place in the XXXth Olympiad, about 659 years before the Christian Era; but the Author of the preliminary dissertation to the Dilettanti Work on Ancient Sculpture, observes, that if the presents offered by Crœsus at Delphi were made for the purpose, as was most probably the case, Theodorus must have been living above a hundred years later than Pliny has placed him. But it is possible that Crœsus may have had the vase already in his possession, and, without having had it made purposely for him, may have considered it, from its magnificence, worthy to be dedicated with his other presents to the Temple. There were two vases, one of gold, the other of silver; the artist who executed the latter is alone mentioned, and that, very probably, owing to its being a more ancient and celebrated work; had they both been executed at the same time, that in the most precious material would, in all likelihood, have been noticed more particularly: it is conjectured, therefore, that these artists lived between seven and eight hundred years before the Christian Era.

Employment of metal.

The introduction of casting in brass, if indeed it were introduced into Greece so early, forms an interesting and important epoch in the History of Art; and it may not be improper to offer some observations in this place on the manner in which it was practised in the first Ages; it must be premised that Pliny's accounts of this subject are not very consistent, and we must therefore be careful how far we admit the traditions mentioned by him. The earliest works in brass appear to have been executed in hammer-work, (called by the Ancients Σφυρήλατον,) that is, beaten out with hammers into the shape proposed, and the Statue of Jupiter, by Learchus, before alluded to, was made in this manner. Pausanias is very particular in his description of this work, and says, it was formed of pieces which were afterwards fastened together by means of pins or keys. Another mode of executing figures appears to have been by beating pieces of metal together in the solid till the surfaces became well fitted to each other; the features and parts were then hammered or hewn out of the mass. Two statues, probably of high antiquity, are noticed, of solid gold, one of Bacchus,[*] at Thebes, the work of Onassimedes, and another of Diana Anaitis; these were most likely beaten into form, and worked up according to this process. Pliny's expression[†] respecting the solidity of the Statue of Diana is remarkable. It has been conjectured that the method above described was practised by the Egyptians; a quantity of metal was also saved by beating it out and plating it upon wood, instead of hammering the whole out of a solid mass, and an interesting specimen is shown, in an engraving in the Dilettanti Work on Sculpture, of a small head of Osiris, in which the nucleus, or centre of wood, is still remaining. Homer, when he speaks of works in metal, always refers to this manner of working, that is, by beating it out, and the hammer is invariably the instrument with which he furnishes Vulcan; he also alludes particularly to the custom of plating sheets of metal on a solid body, when Laertes, at the desire of Nestor, comes to gild the horns of a bull about to be sacrificed.[‡] At what time the Art of casting statues in brass into moulds, taken from models, was introduced is uncertain, but it was, probably, of a

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[*] Paus. lib. iii. c. 17, 18.

[†] Plin. *Nat. Hist.* lib. xxxv. c. 12.

[‡] Herodot. lib. iii. c. 60.

[§] Paus. lib. x. c. 38.

[*] Paus. lib. x. c. 12.

[†] *Aurea statua prima omnium* nulla inanitate *in Templo Anaitidis posita*. &c. Plin. *Nat. Hist.* lib. xxxiii. c. 4.

[‡] *Odyss.* lib. iii. v. 425.

comparatively late date in European Greece. The artists who were most distinguished for their success in the Art, even if their claim to having first discovered it be questioned, were, undoubtedly, Rhœcus and Theodorus, who were both Samians; and the first European Greek, if we except Gitiadas, (whose date is hardly ascertained, and of whose practice but little is known,) who is recorded as having excelled in this branch of Sculpture, lived many years after them; this was Glaucias, the Æginetan, who was employed by Gelon, King of Syracuse.

Dipœnus.
Scyllis.
B. C.
776.

The History of Dipœnus and Scyllis will be found in the Biographical notice before alluded to, where they are placed at 776 B. C. These artists were distinguished for their skill (extraordinary at that time) in working marble;* and appear to have been employed in many important works at Argos and Sicyon. They had many scholars, and we read of the names of Tectæus, Angelion, Doryclidas, Medon, and others, of whom it is not necessary to enter into any account here.

Bupalus.
Anthermus.

The names of Bupalus and Anthermus, who lived soon after Dipœnus and Scyllis, deserve, however, to be more particularly noticed, as they distinguished themselves by a variety of works of a high character, which were preserved at Chios and other places. A group of the Graces by Bupalus, at Smyrna, is highly spoken of, and it is worthy of remark, that at this period the Graces were always represented draped. Pausanias says, Bupalus was an able Architect as well as Sculptor.

Bathycles.
B. C.
600,
to
B. C.
550
or
530.

Bathycles the Magnesian, who is celebrated as the author of the Throne of Apollo, at Amyclæ, is supposed to have lived about 600 years before the Christian Era; some writers have brought his date down rather lower, and have placed him at about 530 B. C.

The Plastic Art was carried into Italy, according to Pliny,† about this time, or rather earlier indeed, by Demaratus, who, accompanied by Euchirus and Eugrammus, two Corinthian artists, fled from Corinth after the usurpation of Cypselus, and the consequent expulsion of the Bacchiadæ; but it must have been known in Italy, it is conceived, at a much earlier period.

The time at which we have now arrived is one of the most remarkable in the History of Greece, whether it be considered with reference to the progress of Philosophy, its political changes, or to the general advancement of Science, Art, and Literature. Pythagoras and the Sages of Greece appeared; Solon legislated; Pisistratus obtained the Government of Athens; and Cypselus usurped that of Corinth: Tragedy was improved by Thespis, and, from being a mere rude Chorus without arrangement, became regularly organized and subjected to rules; the sublime Poems of Homer were now first collected and arranged, and publicly read to the Athenians; the Panathenaic Games were instituted, and the magnificent Temple of the Olympian Jupiter was founded at Athens. About this time also, the custom of permitting statues to be erected and dedicated by the conquerors in the Public Games was introduced, from which, as has before been observed, the greatest advantages resulted to the Art of Sculpture.

The Arts, which had been making rapid progress in the Colonies in Asia, received about this time a paralyzing check in consequence of the unsuccessful revolt which had been attempted by them against Darius Hystaspes. The Cities and Temples of the offending colonists were entirely demolished, the inhabitants were distributed over the Country, became slaves, and were otherwise subjected to the most degrading punishments; but as Art fell in Asia, so it appears to have gained fresh vigour in Europe; the Schools of Ægina, Sicyon, and Corinth sent forth a vast number of eminent artists, who diffused the principles of an improving and grand style throughout the neighbouring States, and we find the Italian and Sicilian Colonies shortly became so distinguished that they were on a level with the Mother Country.

Sculptur
from
Ægin.

To a period not very remote from that under consideration may be attributed the very interesting remains of Sculpture discovered amongst the ruins of a Temple, in the Island of Ægina, which are now in the King of Bavaria's collection, at Munich; they decorated the pediments of the Temple, and, as they were found immediately under the situation which they must have occupied originally, their arrangement and composition were easily ascertained.*

The subject to which the statues refer has engaged the attention of many of our men of letters and verts, but no satisfactory opinion has yet been given of them. All the figures of the Western pediment were found, and, as is evident from their actions, are engaged in some important contest; the figure of Minerva occupies the centre of the pediment, forming the apex or highest point of the composition; she is not only raised on a sort of plinth, but is of larger proportions† than the figures about her, and appears to be presiding over the events taking place in the field of battle. She is represented fully armed; her helmet on, the ægis covering her breast, and her shield on her left arm. The right arm is bent and crosses the body; in her hand she probably held a spear. Immediately in front of the Goddess, appears a dying warrior, who is extended at her feet; another advances towards him, apparently for the purpose of rendering him assistance, while a third figure, with his spear raised, seems to rush forward from behind the wounded man to prevent his approach; the rest of the figures are engaged in various ways with bows and arrows or spears, and the ends of the pediment are occupied by wounded and fallen warriors; the whole, exclusive of the Minerva, amounts to ten statues. Of the figures in the Eastern pediment, but five‡ were found, and they also represent persons engaged in

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* *Marmore sculpendo primi omnium inclaruerunt Dipœnus et Scyllis geniti in Cretâ insulâ.* Plin. lib. xxxvi. c. 4. This is Pliny's account, who gives their date, *Olympiade circiter* L. Pausanias, however, says, they were considered by some to have been the masters of Learchus, of Rhegium, which would make them considerably earlier. Their having been called the scholars of Dædalus leads also to the probability of the earlier date of Pausanias being correct. Paus. lib. iii. c. 17. Flaxman places them at 776 B. C., though he admits, generally, the chronology of Pliny. (*Lect.* p. 75 and 79.)

† Plin. lib. xxxv. c. 12.

* An account of this discovery, which was made in the year 1812, by Messrs. Cockerell, Foster, and the Baron Haller, with some interesting observations on the marbles, is given in the *Quarterly Journal*, No. XII. 1820.

† The colossal dimensions of the Divinities, compared with mortals, are quite consistent with the descriptions of the Poets; in the combat between Minerva and Mars, (Hom. *Il.* lib. xxi. v. 409, *et seq.*) the Goddess throws an enormous mass of rock at her opponent, which strikes him to the earth, and Homer says, he covered seven acres. "Ἑπτὰ δ' ἐπέσχε πέλεθρα.

"Thund'ring he falls, a mass of monstrous size,
And seven broad acres covers as he lies."

‡ That is, but five statues sufficiently preserved to lead to the assurance of their original destination and design; the fragments of twenty-five statues were found on the whole, besides four female statues which adorned the acroteria.

culpture.

combat. It is remarkable that they are all of larger proportions than those of the other side, and that the conception and execution of the statues at this end are of a grander and higher character than those of the Western pediment.

ate III. g. 1

These Sculptures offer many peculiarities of manner and execution, and are highly deserving the attention of the curious. The general style is what is termed Archaic, but the statue of the Goddess is much more so than the rest of the figures; she is entirely draped down to the ancles; the feet, which are raised as if on sandals, are shown, and are both turned in the same direction, as if the figure were standing sideways; the folds of the drapery, which has the appearance of starched or stiffened linen, are thin, and arranged with great regularity, running in parallel lines, the zig-zag edges corresponding on each side; the ægis is smooth, but scales were originally painted or gilt upon it, and some faint remains of the colours are still visible. The extremity or outer edge has a sort of border of snakes, which at regular distances are terminated by small pieces of metal, some of which are still remaining twisted in a corkscrew shape; the helmet also of this, as well as of the other figures, appears to have been decorated with metal, as the holes for its insertion are evident in many of them. It may be observed here, that, with respect to costume, these marbles offer some of the most interesting details of any monuments which have come down to us: some of the figures are completely armed in cuirasses, greaves, and helmets, and the manner of buckling and fixing on the different parts is very carefully represented. The fastenings appear in most instances to have been made of metal; unfortunately the pieces are lost, but still sufficient remains to show the way in which it was done. The costume of one figure is peculiar, the dress is apparently composed of leather; it covers him entirely from the throat to the ancles, fitting closely, and without folds, to the body; his head-dress resembles a high Phrygian cap, and he is kneeling on one knee in the act of discharging an arrow.

ate III. g. 3.

In the execution of these Sculptures considerable skill is indicated, and an advanced state of knowledge in Art is exhibited both in the style which pervades the work generally, and in the understanding and expression of form; there is a grand division and breadth of parts, though the details are not always graceful, and in the articulations of the bones, and the nicety of execution of the joints, there is much to admire. The heads are uniformly in the same style, and of a much earlier character than the body and limbs; and this confirms an opinion which has been before hazarded, that in works of a certain class, illustrating the actions of Divinities or Heroes, (as appears to be the case in these marbles,) or connected in any way with Religion, the treatment of the heads was prescriptive, and, however artists might have ventured to improve upon the less important parts of the figure, that the character, and even the details of the head, handed down through a long course of time and sanctified by usage, were not permitted to be altered; the features are sharp, the eye long and narrow with considerable projection of the upper and lower lids, the mouths in all slightly opened, wide, and, whatever the employment of the figure, smiling; the chins long and pointed, and the edges of the lips, eyelids, and *os frontis* very strongly and sharply marked; the hair is in small curls or knobs, like shells, arranged with great regularity, and falling in long, waving, and wiry lines down the back, corresponding, in fact, to the general mode of treatment which, from Coins and description, we know to be the characteristic of works of the earliest date. The exact period of the execution of these Sculptures has not been ascertained, but judging from the style, which approaches very nearly to that found in the works of the artists who immediately preceded the School of Phidias; considering also the high character of the Æginetan School, and the eminent artists who composed it, it may be inferred that they were not very remote from the period which our History has now reached, namely, between five hundred and six hundred years before the Christian Era. The learned Müller, indeed, inclines to an opinion that they were of a considerably later date than that to which they are here referred; he draws his conclusion from the style of the Architecture of the Temple to which they belonged, and also from the costume of the archer, which he considers Persian, and says they were subsequent to the battle of Salamis.*

Grecian Archaic.

Sculpture from Selinus.

Amongst the remains of Sculpture of a very early date which have reached our times, may be reckoned the fragments found, in the year 1823, at Selinunte, in Sicily.† Two English Architects, prosecuting their studies in that Country, were induced to make some excavations amongst the extensive ruins of the Temples there, and the result was the discovery of several pieces of Sculpture, forming part of the metopes of the Temples. The originals are now in the Royal Museum at Palermo, but casts from them are preserved in the British Museum. There are some peculiarities about these specimens which seem to offer characteristics of two different styles of Art; those which belonged to one Temple (called the Eastern) having much of the character of Æginetan Sculpture, while those of the Western have the appearance of coming from a more barbarous School. It is difficult, without having the works before us, to describe those slight variations in the treatment, as well as execution, which have led to this opinion; but a careful examination of them, and a comparison of what remains of the Minerva, and the head of the dying or wounded figure, with some others of the collection, will explain the grounds on which it is presumed they were executed by different artists. The head of the dying figure resembles very nearly the character of the Ægina warriors, though there is certainly a superiority observable in the expression of the face; the anatomy again is inferior; in the other figures the anatomy is very similar to that on the earliest Coins, but still varying in some respects from the Greek Sculptures; and there is a plump and short character of face approaching in some degree to the Egyptian. At first sight, they strike as being decidedly a branch of Æginetan Art—short proportions, the fleshy portions of the thighs overcharged—the hair dressed in knobs corresponding very nearly with the works of that School; but there still are variations, which, if they were executed at

Plate I. Fig. 5, 6, and Plate III. Fig. 3, 4.

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* *Illas enim post bellum Salaminium factas esse tum ædis cujus in fastigiis positæ erant Architecturæ ratio, tum vestis sagittarii Persici in Paride diligenter repræsentata, mihi quidem persuasere.* C. Odof. Müller, *de Phid.*

† An interesting account of the excavations, embellished with accurate engravings of the more perfect Sculptures, has been published by Mr. Angell, one of the gentlemen to whose exertions the discovery of these interesting works is owing. The drawings were made on the spot, by his companion, Mr. Harris, an Architect of great promise, who unhappily fell a victim to the malaria of the Country, soon after the successful termination of their labours at Selinunte.

the same time, induce us to believe they were not by Sculptors educated in similar principles. At a much later period than that to which these Sculptures are referred, artists from Ægina were employed by the Tyrants of Sicily; and it is, therefore, highly probable that in more remote times, when Sculpture must have been still less known and practised in the Island, that foreign practitioners would be called in to assist in decorating the principal Temples of a newly-founded city: some of the artists so called upon were in all probability from Greece; others may have been brought over from the opposite coast; and their being Carthaginians would, perhaps, account for a certain Egyptian character pervading the faces of some of the figures.

Phigalian Sculpture. The Sculptures in *alto rilievo* in the British Museum, known as the Phigalian Marbles,* are from the Temple of Apollo Epicurius; the subjects they represent are the battle of the Centaurs and Lapithæ, and the contest between the Greeks and Amazons. There is great ability displayed in the execution of these marbles, although some heaviness and disproportion are observable in the figures; the conception of the whole, and composition of the various groups are, however, remarkably fine, and compensate in a great measure for the defects alluded to. The circumstance which renders these marbles particularly interesting, is the knowledge of the time at which they were executed; for Pausanias† says that the Temple of Apollo Epicurius was built by Ictinus, the Architect who superintended the construction of the Parthenon at Athens; and though the Phigalian Marbles want the purity of design and execution which distinguish the Athenian works, the high qualities they do possess claim the second place for them in our estimation.

Sicyon and Ægina were the most celebrated places in ancient times for the production of works in brass. Of the former School we have already had occasion to mention some very distinguished members. **Callon.** Callon‡ was probably one of the earliest Sculptors of that of Ægina who attained reputation, but there is great difficulty in coming to any conclusion as to the exact time at which he lived; and as we merely find a wooden statue of Minerva, mentioned by Pausanias as his work, and an observation in another author on the dryness of his style, his history does not appear very important. **B. C. 500 to B. C. 400.** The Æginetan artists of the greatest celebrity at a later date, were Glaucias and Onatas, the son of Micon; **Glaucias, Onatas.** the former§ was employed by Gelon, King of Syracuse, to make a chariot and four horses, which he dedicated in the Altis, or Sacred Grove, at Olympia, upon having gained the prize in the chariot-race. Onatas and Calamis afterwards worked for Dinomenes, the son of Hiero, who succeeded Gelon. The former of these Sculptors appears to have enjoyed a very high reputation, and Pausanias supplies us with a copious catalogue of his works. Amongst those more particularly noticed, was a statue of Apollo, in brass, of colossal dimensions, at Pergamus; a Ceres, which he made for the inhabitants of Phigalia; and a number of works which were at Olympia. Associated with Onatas is Calliteles his scholar, and probably his son; but the ancient writers do not furnish us with any account of works executed by him independently of Onatas, whom he is said to have assisted in making a statue of Mercury carrying a ram, which was dedicated at Olympia. **Grecia Phidian.** The Sculpture of the Æginetan School of this time had much in its character that was grand and imposing, and a careful observer will discover in the large masses of the muscles, and the bold divisions of the parts, the preparatory step to that perfection which the Art soon after attained.

Consequences of the Persian invasion. An event of the highest importance to Greece, and which tended in no slight degree to aid the progress of Sculpture, happened about this time; this was the celebrated expedition of Xerxes, which, by its failure, discovered to the Athenians the wealth of Asia, while it exposed the weakness of the invaders. It was a custom in Greece to dedicate a tenth of all spoils gained in battle to the service of the Immortal Gods: and a tenth of that obtained from the Persians was appropriated to this high service. Temples were erected and embellished far surpassing in beauty and magnificence those which had been demolished; and happily for the advancement of Art, the opportunities this application of wealth afforded for its improvement, were met by a greater quantity of talent in the respective professions of Architecture and Sculpture than had ever before appeared. This ample employment, and the high object to which their works were destined, to honour the Gods and commemorate the glory of their Country, excited a spirit of honourable emulation in the artists which called forth all their powers, and led to that perfection in Art which even at this remote period we contemplate with the highest admiration.

II. Phidian period. II. The Sculptors contemporary with, or who immediately followed, the period last under consideration, were Hegias, Ageladas, Phidias, Pythagoras, Myron, Polycletus, Alcamenes, and others; and we are, therefore, fast approaching the time when Sculpture reached its maturity. Information of considerable value and interest at this stage of our inquiry is afforded by the ancient writers, some of whom have traced, as far as their own observation of monuments enabled them to do so, the chain of improvement in style in Art, from the School which has been denominated Æginetan to that of Phidias, and it may not be amiss to take a general survey of their classification of the most striking peculiarities of the Sculptors of the respective times. Callon, of Ægina, lived in all probability between 560 and 500 years before Christ: his works, with those of Egesias, are characterised as being hard, approaching very nearly to that distinguished as the Tuscan or Etruscan manner;* Calamis, who succeeded him, was less rigid, and the style of Myron, who followed next, still more softened. Cicero alludes to the same variations in style, bringing us down in like manner to one of the contemporaries of Phidias; the statues of Canachus, he observes, are rigid and hard, not resembling the truth of Nature; those of Calamis also are hard, but less so than those of Canachus; even Myron did not succeed in imitating Nature correctly, yet he surpassed Canachus, and his works may be considered very beautiful; Polycletus, however, was still more fortunate, and his productions are pronounced

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* They were discovered, in the year 1812, near Paulizza, supposed to have been the ancient Town of Phigalia, in Arcadia, by Messrs. Cockerell, Foster, the Baron Haller, and M. Linckh.

† Paus. *Arcad.* c. 14.

‡ Paus. lib. ii. There was more than one Sculptor of this name.

§ Ibid. lib. vi.

* *Duriora et Tuscanicis proxima Callon atq. Egesias, jam minus rigida Calamis,* &c. Quinct. *Orat. Instit.*

lpture. to be perfect.* The History of the Art is thus, it will be observed, carried out of the Æginetan into a more polished School, to which therefore our attention will now be more particularly directed; the principal artists who effected the change in the style of Sculpture having been mentioned above, it remains now to notice them individually, as some observations on their respective manner will lead to the better understanding of the excellence of Phidias. We must first take notice of a Sculptor of Rhegium, whose works have been frequently referred to, and who appears to have had very just claims to the distinguished rank he held amongst the artists of antiquity. Some of the productions in brass of the earliest practitioners of that colony, executed at a time when that material was hardly known for the purposes

agoras. of Sculpture, have already been noticed, and Pythagoras, the subject of our immediate attention, seems to have supported the credit of the School of which Learchus (who was perhaps the founder at Rhegium) and others were such distinguished members. From the difficulty which exists in making the execution of the productions of Pythagoras correspond with the times at which we find the name mentioned, it has been supposed, and with great apparent reason, that there was more than one Sculptor of Rhegium so called. The chief of the name was a scholar of Clearchus, (also of Rhegium,) or more correctly speaking, perhaps, of the School of Clearchus. An improved taste in execution seems now to have been introduced, and more attention than usual was paid to expression; a statue by Pythagoras of a wounded man is recorded, in which the expression of anguish was so admirably defined that the spectators were affected by it, and seemed to share with the figure the pain he was supposed to be suffering. Pythagoras, too, is particularly noticed as being the first who represented the veins† and nerves in his statues; he was also more careful in the execution of the hair than his predecessors.

n. Myron, of Eleutheræ, or of Athens, and the scholar of Ageladas, is the next Sculptor of celebrity who claims our notice. Pliny‡ gives him the preference in some respects even to Polycletus, and says that he introduced a greater variety in his Art than those who preceded him; but he observes at the same time, that he was not successful in expressing the feelings or passions of the mind, nor did he make any improvement in the manner of treating the hair, which was stiff and formal, as in the times of the rudest Art; his style was, in all probability, hard and minute, but he must still be considered one of those Sculptors by whose assistance the Art

V. was brought to excellence. We possess a very interesting specimen of this master's manner in a statue in the British Museum of a *Discobolus*, or Quoit-thrower, generally believed to be a copy of the famous statue by Myron, so minutely described by Lucian and Quinctilian;§ and though there is considerable dryness of manner in this work, it nevertheless possesses qualities which claim for the Sculptor a higher character than Pliny's account of him would alone have justified us in awarding him. The great excellence of Myron seems to have been shown in his productions in brass, in which he was the rival of the famous Polycletus; and we are told that Myron used the bronze or brass of Delos, while Polycletus employed that of Ægina for his works.* Grecian Phidian.

There appear to have been at least three Sculptors called Polycletus, but there is so much confusion on this point in the authors who have mentioned them, that it is almost impossible to distinguish between them; it is evident, however, that two were called *Argivi*; Pliny, indeed, calls the most celebrated *Sicyonius*, but as he is the only writer who gives him that title, it has been thought probable that both Sicyonian and Argive may have been correctly applied to the same artist, *Sicyonius* as a native of Sicyon, and *Argivus* also from his having been admitted to the rights of citizenship at Argos, where he studied and executed many of his most important works. He appears to have been an artist of very high celebrity, and, according to History, was remarkable for the great care and attention with which he finished his productions; indeed, he was the author of a statue so perfect in its proportions that it was called by common consent the *Canon*, and referred to as the "Rule of Art."† Polycletus seems, from the criticisms which have reached our time, to have been deficient in that variety which is so essential to the accomplishment of an artist. Some further particulars respecting this Sculptor will be found in the BIOGRAPHY OF THE EARLY SCULPTORS OF GREECE. Polycletus.

Hegias, or Hegesias, for it is presumed the same person is meant, and that the name is only varied by the corruption of ancient texts, was classed, as has been noticed above, amongst those artists whose style was hard and dry. Hegias.

Of Ageladas, we have no information which will tend to illustrate this part of our subject, and a mere list of his numerous works, with the conjectures of antiquaries respecting the time at which they were executed, must be considered as belonging to the History of the artist individually, rather than that of Sculpture generally; the circumstance of the greatest interest connected with Ageladas is, that he was the master of Phidias, Polycletus, and Myron, three of the brightest names in the Annals of Art. Ageladas.

It must be admitted that the Sculptors in the Æginetan class of Art immediately prior to this time, laid the foundation of that fine style which Phidias brought to perfection; yet the suddenness of its consummation has given the Sculpture of his School a character that may almost lay claim to originality, particularly when it is recollected that even some of his contemporaries are noticed for still clinging with partiality to the dryness of style and peculiarities of execution of the Æginetans. Phidias, the son of Charmidas, was a native of Athens,‡ and was born about the LXXIIId Olympiad, or 484 years before Christ. Of his early life and studies but little is known, though it is said he at first studied the Art of Painting; the circumstance of two of his family having been Painters may have led him to amuse Phidias. B. C. 484.

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* *Quis non intelligit Canachi signa rigidiora esse quàm ut imitentur veritatem? Calamidis dura illa quidem, sed tamen molliora quam Canachi; nondum Myronis satis ad veritatem adducta, jam tamen quæ non dubites pulchra dicere. Pulchriora etiam Polycleti et jam planè perfecta*, &c. Cic. *de Clar. Orat.*

† Plin. *Nat. Hist. Hic primus nervos ac venas expressit, capillumque diligentiùs.*

‡ Ibid. lib. xxxiv. c. 8.

§ *Quid tam distortum, et elaboratum quam est ille Discobolus Myronis*, &c. Quinct. *Orat. Instit.* and Lucian *in Philopseude.*

* Plin. *Nat. Hist.*

† *Fecit et quem* Canona *vocant, lineamenta artis ex eo petentes velut a lege quâdam.* Plin. *Nat. Hist.* lib. xxxiv. c. 8.

‡ Pausanias gives the inscription on the statue of the Olympian Jupiter, declaring it to be the work of Phidias, the Athenian, the son of Charmidas. Φειδίας Χαρμίδου υἱὸς Ἀθηναῖος μ' ἐποίησε: and see Strabo, &c.

himself in that branch of the Arts, but the authority for his having followed it, as a profession, is so slight that no great dependence can be placed on it, and it is probable that, if he did at any time employ himself in it, he soon relinquished it, and dedicated himself entirely to that Art in which he was destined to become so distinguished. His masters, we are told, were Hippias and Ageladas: of the former but little is known;* the latter enjoyed a high reputation, and executed many works of importance. Circumstances were particularly favourable for the display of the talents of Phidias; he had the advantage of living in Athens during the enlightened administration of Pericles; and, being highly esteemed by that distinguished statesman, was consulted in all works that were undertaken for the embellishment of the city.† Plutarch, speaking of the magnificent edifices erected during his government, says, "These structures, stately as they were in magnitude, and inimitable for their graceful forms and elegance, (every artist being ambitious that the excellence of the workmanship should equal the beauty of the design,) were yet more wonderful for the expedition with which they were accomplished."—"It was Phidias who had the direction of these works, although great Architects and skilful artificers were employed in erecting them."‡ The works for which Phidas has been most celebrated were his Statue of the Olympian Jupiter, at Elis, and that of Minerva, in the Parthenon at Athens. It will not be necessary here to enter into a minute description of these works, as, in the BIOGRAPHY OF THE EARLY SCULPTORS OF GREECE, a sufficiently accurate account of them has been supplied; and the reader who desires further information on the subject is referred to Pausanias, Pliny, Strabo, and other authors of antiquity who have been particular in their descriptions of the productions of Phidias. They were of colossal dimensions, and composed of ivory and gold. The statue of Jupiter was represented seated on his throne, and it seems to have been the object of the Sculptor to exhibit him, as far as was consistent, as a local Deity. He was to be placed in a magnificent Temple erected in the Sacred Grove, close to the spot where the most important of the Games of Greece were celebrated, and surrounded by the statues and votive offerings of the victors; Phidias, therefore, made him the presiding Deity of the place, the judge of the Games, and dispenser of victory; he was not armed with the thunderbolt, nor was he surrounded by any of the more majestic attributes which would have distinguished him as the King or Father of Gods and men; but his brows were encircled with a wreath of olive, the reward of the successful competitors, and in his hand he supported a statue of Victory. We purposely abstain from any minute description of this work for the reasons before stated; but we are induced to mention a tradition connected with it, which becomes interesting from its exhibiting the importance which the enlightened Greeks attached to productions of this high character. Phidias, after the completion of his work, is said to have besought the God, in whose honour the statue was erected, to favour him with some intimation whether it was pleasing to him; immediately a flash of lightning struck the pavement before him: this was at once hailed as a proof of the satisfaction of the Deity; and in commemoration of the event a brazen vase or urn was placed on the spot, which Pausanias says was existing in his time.* The statue of Minerva was standing, and fully armed; its height we are told was twenty-six cubits,† and the gold employed on it is said to have weighed forty talents.‡ Phidias executed several statues of Minerva, his Country's protecting Goddess, and the patroness of Art and Science; we find eight or nine recorded as having been made for different places, either in gold and ivory, or brass, and one, which was for the Platæans, (and placed in the Temple of Minerva Areia,) was of wood, gilt, excepting the face, hands, and feet, which were of the white marble of Pentelicus. Phidias has been called the Sculptor of the Gods,§ from the grand and sublime character which he invariably threw into his works, and from the particular excellence he displayed in his two great productions, the Jupiter and Minerva; but his genius was not limited, and though his chief power seems to have been in works of the highest and most dignified class of Art, yet it was not only in statues of a severe character that he employed his talent, for we find amongst his works various statues of Venus, Mercury, and Apollo, as well as of an Amazon, which latter was executed in competition with other highly esteemed artists of his time. Our readers, who desire to become more fully acquainted with this great Sculptor's life, are referred to Müller's learned disquisition, *De Phidia Vitâ*, where also will be found some valuable information on the probable dates of the execution of his masterpieces, the colossal Jupiter, and the statues of Minerva.

Marbles from the Parthenon.

Unfortunately, no remains of his greater works have reached our times; but we are enabled in some measure to estimate the power of this artist from those productions which have been spared to us forming the decoration of the Parthenon. The Sculptures of the pediments, the metopes, and portions of the frize which form so valuable a part of our collection of Greek Sculpture in England, are convincing proofs that the encomiums of the Ancients were not accorded without reason. There can be no doubt that these were works of Phidias and his scholars; and in vain shall we look for specimens which, generally speaking, bear more unequivocally the distinguishing marks of the master mind and hand; or which exhibit finer examples of that grand style of which Phidias has been justly esteemed the founder.|| The qualities for which these works claim our admiration will be found to consist principally in their truth to Nature: but it was not Nature copied servilely, and without selection, but viewed under particular feelings, and with a strict and careful examination of what was fit and beautiful; and thus was that combination produced

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* He is mentioned by one writer only, Dio Chrysost. *Or.* lv.

† It is remarkable that there is no Statue of Pericles by Phidias, nor do we find any mention in the Works of the Ancients of his having ever executed any portrait of his patron, if we except that introduced in the shield of the Minerva of the Parthenon, and which was of course only in *basso rilievo*.

‡ Plut. *in Vit. Pericles*.

* Paus. lib. v. c. 11. We have no positive information respecting the height of this statue, but Strabo informs us that, if it had stood up, it would have been higher than the roof of the Temple, and he makes a very just observation that the statue was therefore disproportioned to the building.

† Plin. *Nat. Hist.* lib. xxxvi. c. 5.

‡ Thucydides.

§ Quinctilian, lib. xii. c. 10.

|| All these Sculptures are not, it is true, executed with the same correctness of detail, but these inequalities are to be attributed to the greater or less degree of talent in the inferior workmen whom it was necessary to employ in getting such extensive compositions executed.

lpture.

Grecian Phidias

which has in after-times been called *Ideal Beauty*. That no works contained this before the time of Phidias may be judged by many monuments remaining to this day; that the productions of his School possessed this quality in an eminent degree the Elgin[*] collection of Marbles sufficiently testify. The statue of the Ilyssus or River God, the Theseus, the Neptune, and the draped groups, mutilated as they are, have a grandeur, simplicity, and truth to Nature in them that strike the commonest observer; it requires no teaching to understand that the attitudes are perfectly easy, that the balance of the parts is just, and that the general character is natural. These are qualities in imitative Art which every person who observes Nature at all is able to appreciate, and to do which no initiation into the arcana, or details, is requisite. Nor is it in the naked figures only that this excellence is exhibited; his draperies are treated with the greatest skill and attention; they are plentiful and rich in their effect, and yet so arranged as to show the action and form of the limbs beneath, exhibiting (as has been well observed of this great Sculptor) with the greatest art the greatest simplicity. Our observations on Phidias have been purposely condensed as much as possible; the History of himself and of many of his works, the time of their execution, and the circumstances under which they were produced, offer subjects for a very extended Treatise; but, for obvious reasons, we must not enter upon details which would lead us beyond the limits to which the History of the Art, and not of the artists, should confine us.

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Although Phidias exercised his skill as a Sculptor in all the materials which were in general use for the purposes of his Art, gold, ivory, brass, marble, and even wood; yet his productions in the former, a mixture of gold and ivory, (*Chryselephantine* Sculpture, as it is generally termed,) appear to have been the most highly esteemed, both from the extensive scale on which he used such rich materials, and from the great importance of the works to which he applied them. We have deferred entering into any description of this branch of the practice of the Art till the Age of Phidias, as it must be considered to have attained its perfection at or about the time in which he lived. Its adoption for works in Sculpture may be traced back to a period considerably earlier, as, for instance, in works existing in the *Heræum*, or Temple of Juno, at Olympia, and in other places described by Pausanias, to which this general reference will be sufficient; but none of the Sculptors who preceded Phidias appear to have employed it on so large a scale as he did.

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Chryselephantine Sculpture is a branch of what the Ancients called *Toreutic* Art; which term, it is presumed, was intended to express the uniting of metals with other materials; the phrase has caused much discussion, and almost all the modern commentators and writers on Art have considered the subject with attention; but each has explained the term according to his own conception, and unfortunately a very great difference of opinion still exists as to its precise meaning. We cannot attempt to give the reasons which have influenced their conclusions, but we venture to explain the term generally, applying it to Sculpture, whether in *basso rilievo* or the round, in which a variety of materials, always including metal of some description, were used. Pliny pays a high compliment to Polycletus in speaking of the Toreutic Art, as it was practised by him and Phidias, and says, that Polycletus brought it to perfection;[*] but this may be understood as applying merely to some mechanical improvements, either in polishing or fastening the pieces together; as the great work of Polycletus, his Juno, was executed subsequently to the Olympian Jupiter of Phidias; and he, therefore, had the opportunity of seeing where any variations in these respects could be made with advantage. The statue of Phidias, we are informed, required repair very soon after his death, but we do not hear that the great work of Polycletus was subject to the accidents which affected the Jupiter, and which he avoided, probably, from the experience he gained by Phidias having made the first essay on a large scale; viewed in this light the passage in Pliny becomes at once intelligible.

It is somewhat difficult to understand how the Greeks of this time, who appear to have felt the value of simplicity in Art so thoroughly, should have executed and admired works composed of materials, which, it is natural to suppose, would injure, if not destroy the effect of the more intellectual part of them, if we may be allowed that term, applying it to expression and fine form; but we know that the great statue of Jupiter was not only composed of gold and ivory, but that it was also richly painted, and ornamented throughout in the most elaborate manner. We certainly have no means of judging what was the precise effect of such varied materials employed on a large scale; at first it seems to militate against the pure taste which we fancy pervaded all the productions of the Greek artists, and yet, when we find Phidias himself adopting it, it will look like presumption to question its propriety. The accounts, too, of those writers who had the opportunity of seeing these works in their most perfect state, convey an idea that nothing could be more magnificent and imposing; that they were not merely gorgeous to the sight, but there was that in them which seemed to add to the dignity of Religion.[†] A few observations on the means which the Ancients are supposed to have adopted for executing colossal works in these combined materials, may not be irrelevant; our notice of it must be very general, but to those who desire to enter more minutely into the subject, the valuable Work of M. Quatremère de Quincy *sur le Jupiter Olympien*, is recommended; in which the history of Chryseliphantine Sculpture is particularly considered, and traced from its earliest introduction to the period at which it appears to have been brought to perfection; and a list of the artists who were most distinguished in it at any time, and of all the most celebrated works, is supplied, as well as a variety of highly interesting details of the manner of employing it.

Mode of executing Chryselephantine work.

The first step appears to have been to make a model of the full size of the work proposed to be executed; this being completed, a rough copy or general resemblance of the model was made in wood, to answer the purpose of a nucleus, or centre, to which the ivory was to be attached. This model does not appear to have been solid, for within it were the irons and necessary supports for the safe fixing of the whole to the pedestal, and also for the security of the parts, as head, arms,

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[*] So called from their having been brought from Athens to this Country by the Earl of Elgin, of whom they were afterwards purchased by Parliament.

[*] *Hic consummâsse hanc scientiam judicatur, et Toreuticen sic erudisse ut Phidias aperuisse.* Plin. lib. xxxiv. c. 8.

[†] As Quinctil. lib. xii. c. 10. observes of the Olympian Jupiter.

&c.; it is also probable that it was requisite to have the means of getting within the work, for the purpose of taking care of it, and repairing it, in case any of the parts or pieces of the ivory should start from their places. The wooden model, or groundwork, being completed, the surface was produced by closely fitting small pieces or plates of ivory upon the wood by means of pins and cement; whether the ivory was worked and finished to a scale before it was attached to the nucleus or under model, or afterwards, (being merely generally prepared in point of form,) is left to conjecture; but the latter appears the most probable, as well as the easiest and surest mode of proceeding. In the Olympian Jupiter, indeed, Phidias appears to have worked the ivory in pieces in his study. Pausanias[*] says, near to Altis is an edifice which is called the workshop of Phidias; and he adds, it was there that this artist worked each of the parts of the Jupiter; still this working in pieces may mean general form, for it is unlikely that each should have been made perfect first, and then fastened to the model or centre. The ivory part of the work being completed, the attachment of the drapery and ornaments in gold or other metal, either cast or beaten out, offered no difficulty. Ivory was found to be particularly subject to the influence of the atmosphere, being equally affected by excessive dryness, or by too great humidity, which would also act considerably on the wood used in the construction of the work, causing expansion or contraction to the injury of the joints; the preservation, therefore, of these works required considerable attention, and Pausanias alludes to the means adopted for this purpose, when he speaks of the principal Chryselephantine works in Greece. The Olympian Jupiter was surrounded by a ledge of black Parian marble,[†] to contain oil; this was to preserve the ivory damp, and at the same time to prevent too great a degree of moisture from rising to it, the Altis being marshy ground. The charge of taking care of this celebrated work, we should observe, was intrusted to the descendants of Phidias, under the title of *Phædruntai*,[‡] who were always obliged to sacrifice to Minerva Ergane before they commenced their functions; and we are informed that this office was in the same family down to the time of Hadrian. Pausanias acquaints us also with the manner in which the Minerva of the Parthenon was preserved, the situation of the Acropolis of Athens being dry and unfavourable to the ivory. It is unnecessary to enumerate them here; but particulars in confirmation of the Ancients having paid the greatest attention to the safety of such works, are furnished by Pliny, Pausanias, and other writers, in speaking of the Minerva of Pellene, the Diana of Ephesus, and other statues composed of these materials.

Agoracritus. Of Agoracritus, the favourite scholar of Phidias, a full and interesting account will be found in the BIOGRAPHY of Artists before referred to.

Alcamenes. Alcamenes was one of the most distinguished artists of this School, and was considered by some to be second only to Phidias; one author, indeed, alluding to the progress of the Arts, does not hesitate to class Alcamenes with Phidias himself, saying, that what was wanting in Polycletus was given to Phidias and Alcamenes;[§] and there is a tradition that Alcamenes had the honour to contend with Phidias in executing a work for the Athenians.[*] Two of the productions of Alcamenes are particularly noticed for their excellence; one was a statue of a Pentathlus, the other of a Venus, called "of the gardens."[†] Phidias is said to have given Alcamenes the advantage of his assistance in this latter work. Besides Agoracritus and Alcamenes, we find Colotes, or Colotas, Pæonius, and others, who assisted Phidias in his great works, (having accompanied him to Elis,) and who in all probability were also his scholars; the accounts, however, which we have of them are not of sufficient importance to induce us to enter into their history.

III. After this period, a gradual change took place; Sculpture, freed from the dry manner which characterised the works of the Æginetan artists, attained its perfection in the grand or sublime style under Phidias and his School; but it appears there was still some severity in treatment remaining, which the Sculptors of the succeeding Age exerted themselves to remove. The Art may have lost something of its energy by the introduction of the flowing and graceful style, but the high commendation universally bestowed on Praxiteles and those who effected the change to which we allude, are sufficient to stamp their characters as artists of extraordinary merit. Praxiteles of Cnidus has rendered himself famous for his productions both in brass and marble; and we find that his choice of subjects corresponded generally with the soft, elegant style of Art he is said to have practised; they were for the most part female figures or youths, and he is believed to be the first Sculptor who ventured to make a statue of Venus entirely naked. Millingen,[‡] on this subject, says, all the statues of female Divinities were anciently draped, and that Praxiteles was the first who represented Venus naked; such an innovation was considered extremely indecorous, but excused on account of the beauty of the performance; subsequent artists wishing to reconcile a mode of representation, so favourable to the purposes of Art, with the rules of decorum, adopted the form of drapery seen in the Venus of Capua and Melos,[§] namely, a mantle covering the lower part of the body, and falling to the ground; the statues of Venus which, in imitation of that of Cnidus, are found in a state of nudity, are almost always to be referred to a low period. Praxiteles is mostly celebrated for the perfection to which he brought his works in marble, and the Ancients all agree in the encomiums bestowed upon him for his superiority in this respect; he is also noticed for the truth of expression in his works, and two in particular are recorded as masterpieces; one was of a matron weeping, the other of an entirely opposite character, namely, a courtezan, who was represented with her features lighted up with joy; the latter was said to be a portrait of his favourite Phryne. In proof of the high estimation in which the works of Praxiteles were held by the Ancients, it will be sufficient to mention an anecdote respecting the celebrated naked Venus in marble at Cnidus. Nicomedes, King of Bythynia, offered

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[*] Paus. lib. v. c. 15.

[†] Ibid. *ut suprà.*

[‡] Ibid.

[§] Quinctilian, lib. xii.

[*] Tzetzes, Chil. lib. viii.

[†] Lucian, *de Imaginibus*. Plin. *Nat. Hist.* lib. xxxvi. Pausanias, lib. i.

[‡] Millingen on *Ancient Inedited Monuments of Grecian Art*, No. 10. p. 7; a valuable and highly interesting Work, which, unfortunately for the real lovers of Art and antiquarian research, has never been completed.

[§] The former is in the collection of the King of Naples in the Museo Borbonico; the latter in the Sculpture Gallery of the Louvre.

to liquidate an immense debt under which the Cnidians were labouring, if they would allow him to have this statue; his countrymen, however, were not tempted by the liberality of the offer, but chose rather to submit to their existing pecuniary difficulties, than to part with a work the possession of which was sufficient to render their city illustrious.

The next name of importance, as the head of a School, is that of Lysippus. He was a native of Sicyon, and his reputation was not inferior to that of any of the great men who preceded him; he was the favourite Sculptor of Alexander the Great, and the only artist who was permitted to make statues of him;[*] according to some he executed a series of portraits of this Prince, commencing from his childhood up to his maturer years. Lysippus appears to have worked exclusively in brass, and, according to Pliny, he executed no less than six hundred and ten works; amongst them a colossal statue, which he erected at Tarentum, is particularly noticed. He is said to have made some important improvements in Sculpture, being particularly commended for the attention he paid to the execution or finish of his works; he made the heads of his figures smaller than his predecessors, and introduced a proportion that was more graceful; he appears also to have got rid of a certain degree of squareness still remaining in the style of some of the Sculptors, and to have given a roundness of form not attempted by the preceding Schools. He professed, however, notwithstanding he was so attentive to his finishing, to study effect, rather than to copy details and the minutiæ of forms, at least the remarkable expression he used respecting his practice leads to that conclusion; he is reported to have observed of other artists, that they made men as they really were, he as they appeared to be;[†] which can only mean that he preferred breadth and freedom of parts, such as Nature, viewed generally, exhibits, to the representation of details which, too often, when they are too closely attended to, destroy the unity and breadth of a work. This observation, which would imply a superiority in the style of Lysippus, may appear too bold when the great names of his precursors are considered; but however difficult it may be to explain in writing the peculiarities which characterise style in Art, and which, it must be remembered, often depend upon very slight distinctions, the difference does exist, and will be easily comprehended by those who will examine and compare works, whether Coins or Sculpture, on a more extended scale, of different Ages and Schools. A Sculptor of very high celebrity must not be omitted, who is presumed to have lived about the time of Lysippus; this is Scopas, to whom the celebrated group of Niobe and her children is attributed; these statues are at Florence, in the Gallery of the Grand Duke of Tuscany.[‡]

Lysippus left several scholars, three of whom, his sons Laippus, or Daippus, Bedas, and Euthycrates, are mentioned amongst the most eminent artists who succeeded him; of these the last held the most distinguished rank, according to the account of Pliny. There is a peculiarity, however, remarked in his practice which deserves notice here, as it is an additional confirmation of what has before been observed with respect to adherence to the old style; it is said, that Euthycrates imitated the firmness[*] in his father's works, rather than the elegance for which they were esteemed, preferring, in fact, a certain austereness of character, to the more voluptuous and pleasing manner of execution which Lysippus had adopted.

Euthycrates.

School of Lysippus.

Chares the Lindian, who made the celebrated Colossus at Rhodes, which was ranked among the wonders of the world, was a scholar of Lysippus; as was Tisicrates, a Sculptor of Sicyon, who followed so closely in the steps of his master, that it was often questioned whether works were by Lysippus or his scholar. Pliny may be consulted on the number of Sculptors who were formed in the School of Lysippus, and to whom many works of first-rate merit, still existing, have been attributed by subsequent writers; whether justly or not must at present be a matter of conjecture, but the appropriation is a proof of the estimation in which the artists of this School have been held.[†]

School of Rhodes.

Our observations on the Schools of Sculpture in Greece now draw to a conclusion, the most important features in each, as far as they are illustrative of the progress of the Art, having been considered; before taking leave, however, of the subject, we must make honourable mention of the Rhodians, amongst whom the Arts were particularly protected and studied. The importance of Rhodes was on many accounts considerable, but it especially claims a place here, as some very fine specimens of Sculpture emanated from its School. The Sculptors of the Laocoon, Agesander, Polydorus, and Athenodorus, and of the group of Dirce, commonly called the *Toro Farnese*, Apollonius and Tauriscus, as well as of the famous Colossus, were Rhodians; and it is almost incredible that from this little island, not more than forty miles long and fifteen broad, the Roman conqueror brought away three thousand statues; but we shall the more readily believe this, when we recollect that the force and enterprise of these islanders were sufficient to vanquish the navy commanded by Hannibal. We shall not dwell at any length on the Sculpture of Sicily, which must, in fact, be considered Grecian. Some of the medals of this Country are particularly fine, and are well worthy the attention of the admirers of Art.

Plate IV. Fig. 3.

IV. Decline.

IV. The name, or rather the School of Lysippus, seems to conclude the History of Greek Sculpture up to its perfection; those who followed but imitated what had gone before them, or, if they invented, their works were of an inferior description; it is true many names still occur of great respectability in the Art, but there was neither that genius nor originality in the style or conception of their productions, which claim for them a place

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[*] Pliny, lib. vii. c. 37, says that Alexander issued an order that no artist but Apelles should paint him, Pyrgoteles engrave gems of him, or Lysippus make statues in brass of him. *Edixit ne quis ipsum alius quam Apelles pingeret, quam Pyrgoteles sculperet, quam Lysippus ex ære duceret.* It is remarkable that no mention is here made of marble statues of Alexander.

[†] Pliny, *Nat. Hist.* lib. xxxiv. c. 8.

[‡] There is reason for thinking that the greater part of the statues composing this group are but copies from the original works. We possess in England a head of Niobe, similar in action and expression, but preferable for its style and execution, to that of the statue at Florence, and as we know there are repetitions of some of the figures, our doubts on the genuine antiquity of the statues in the Grand Duke's Gallery are not without foundation. For the above head, *vid. Select Specimens of Sculpture.* Dilettanti, vol. i.

[*] *Ante omnes Euthycratem; quanquam is constantiam patris potius æmulatus quàm elegantiam*, &c. Plin. lib. xxxiv. c. 8.

[†] We possess a fine specimen of the School of Lysippus, perhaps a work of the great master himself, in a small bronze statue of Hercules, in the British Museum.

amongst those who aided the developement and perfection of Sculpture. In our progress through the History of the Art we have taken occasion to mention the principal men who were distinguished as heads of Schools, and it is therefore unnecessary to add a list of all those Sculptors whose names have been handed down to us. The degree of patronage extended to the Arts would, of course, add considerably to the number of artists, as the excellence or celebrity of a master would increase the followers of the favourite style of the time. The enumeration, however, of these is not essential; for, as has before been observed, the object is not to give a History of the artists, but of the Art, and they have only been mentioned when absolutely necessary for the illustration of particular points. It is certain that a much more detailed account might with advantage have been given of the Sculptors, as well as of their productions, but this would necessarily have extended this Essay beyond its proposed length, and would have led to the introduction of matter not strictly belonging to our present subject.

Consequences of the death of Alexander the Great.

By the conquests of Philip of Macedon, and those of his son Alexander the Great, it is but natural to believe, that the light of Grecian Science, Literature, and Art were becoming generally diffused over Countries which had long been in a state of comparative darkness; but not all the advantages which might have resulted from these successes, and might have compensated in some measure for the miseries attendant upon the victor's progress, were suffered to be realized. The death of Alexander opened a field for discord and contention which operated fatally on the durability of the extensive dominion he had attempted to establish, and as fatally on the progress of the Arts in Greece. The Generals of that Prince, thinking only of their own aggrandizement, and removing the legitimate heirs to his vast possessions, divided them amongst themselves as separate Kingdoms, and were soon involved in foreign and domestic broils, the consequence of ambition, usurpation, and tyranny. The Arts continued to flourish for some short time under the most powerful of the successors of Alexander; in Syria they were protected by the Seleucidæ, in Egypt under the first Ptolemies, and at Pergamus by Attalus and his son Eumenes; but they were rapidly declining, and in the wars of this period, not only the sacred treasures were pillaged, but the edifices which contained them were subverted and destroyed, and the statues broken and melted. The artists had the mortification of seeing the finest monuments of genius purposely defaced, and they felt that their own efforts to gain distinction were crushed; the production of works in the higher departments of Art began to be discouraged, and the Sculptors found that their only employment was in portrait statues of those who happened to be in possession of sovereign power; a miserable application of their talents in times of change and violence, as the artist could have but little expectation that his work would last beyond the reign of its archetype.

Gradi Decli

About the CLVth Olympiad, Pliny says the Arts in Greece recovered partially from a state of inertness in which they had remained from the CXXth; but the artists, he observed, were very inferior to those who had preceded them,* and it appears that this was but a last effort, a feeble glimmering, before their final extinction in Greece. This restoration took place probably rather earlier than the time mentioned by Pliny; and between the CXLVth and CLth Olympiad, we find the names of several Sculptors of merit. To this time many antiquaries have referred the celebrated authors of the statue of the Hermaphrodite, and of the mutilated trunk, known as the *Torso* of the Belvidere, which bears the Sculptor's name, Apollonius, the son of Nestor. Of Glycon, whose name appears on the statue of the Hercules,* and of Agasias, the author of the Fighting Warrior, (or Gladiator, as it is generally called,) nothing is known, their names not being mentioned by any author of antiquity; these statues have however been attributed to about this period. In the CLVIIth Olympiad the last blow was given to the power and hopes of the Greeks, by Lucius Mummius, who had been sent by the Roman Senate against the Achæans. He engaged the Greek army near Corinth, the principal city of the famous Achæan League, and having entirely defeated and routed it, the city was immediately given over to destruction, and sacked; and the Romans carried from this seat of the Arts, as well as from other cities equally celebrated, all the fine productions in Sculpture and Painting which had been accumulated for Ages; and Rome became filled with the most splendid monuments of Grecian taste and genius.

Transfer o works of Art to Rome.

Athens, which for various reasons had been the chief and favourite asylum of the artists of Greece, had undergone considerable changes of fortune from the time of Pericles, under whom she may be considered to have arrived at the zenith of her glory. The reverses which affected her political importance, and from which she never recovered, did not, however, affect the cultivation of Literature and the Fine Arts, for which she was celebrated long after her influence in affairs of state was at an end. But after the death of Alexander, we find her struggling in vain to preserve even this ascendency, and she was continually subjected to humiliations and oppressions from his successors, and at last fell into the hands of the all-conquering Romans, and had to bow her neck to the cruel and unrelenting Sylla. On the breaking out of the Civil war between Pompey and Cæsar, Athens sided with the former; but she, happily, felt no additional yoke from the success of Cæsar, who, instead of visiting with vengeance a city whose inhabitants had declared themselves inimical to him, and were the supporters of his rival, treated them with clemency, and, with a fine allusion to their illustrious ancestors, declared, "that he would spare the living for the sake of the dead." The war between Brutus and Cassius, and Augustus and Antony, soon followed, and upon the success of Augustus, and the establishment of the Roman Empire, the Greek artists sought and found an asylum in Rome, where, however, the practice of Sculpture became, in a short time, widely different from that which had distinguished it in its own favourite land. It will be proper, however, to take a general view of the state of Art in the Roman Empire from the earliest accounts of it, to show what had been done in it, and by what accident it became a pursuit of any importance or value with the conquerors of the World; for it will be found that considerable collections of statues in marble and metal, as well as of pictures, were made in Rome, some time before the Art and artists emigrated

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* Plin. *Nat. Hist.* lib. xxxiv. c. 8.

* Commonly called the *Farnese Hercules*; it is now in the Museum at Naples.

pture. from Greece into Italy as an asylum, when they were frightened and driven from their own Country.

Roman Sculpture.

For many years after the establishment of the Romans as a nation, they were too much harassed, at home and abroad, to think of the more elegant pursuits of Society; the History of Sculpture, therefore, amongst them, does not assume any importance till a comparatively late period. The city itself, like its inhabitants, was in the beginning rude and unadorned, and a nation of rough soldiers was not likely to admit the influence or value of the politer Arts, which they could only look upon as the care of an effeminate people. Their first public monuments were trophies; the trunk of a tree, stripped of its branches, was dressed up with the arms of the conquered, and exhibited to public view; and although we read of works in Sculpture of an early date, there can be little doubt that they were the productions of their more enlightened neighbours the Etruscans. It is not very easy to determine at what time the Romans themselves began to think the Arts of Design worthy their attention. Mention is made of equestrian statues erected in Rome in honour of M. F. Camillus and Q. Mænius, after their victories over the B. C. 300. Latins, above three hundred years before the Christian Era; and about the same period, Fabius, a man of noble family, who dedicated himself to the Arts, and acquired the surname of *Pictor*, distinguished himself by painting subjects in the Temple of the Goddess of Health; about this time too a bronze statue of Apollo was erected in the Capitol, out of the spoils of the Samnites. rcellus. After the taking of Syracuse, Marcellus sent works of Art from Sicily; and it is also said, that the first Greek artist who had visited Rome was sent there at this period. The increasing power and successes of the Romans now enabled them to collect various specimens of Art which they sent in great numbers to Rome, but it cannot be said that the possession of the beautiful works which fell into their hands, caused at this time any great improvement in the general taste of the people; the fact is, cities and temples were ransacked and plundered to enrich the treasury of Rome, or to swell the triumph of a general, and works of Art were merely looked upon as spoil;—the feelings, therefore, which the finest display of Art excited amongst the people, were far from any likely to generate a love for refinement, and the quieter pursuits of civilization. It is to be remembered also, that the spirit of the Government was rather opposed than favourable to the encouragement of the Arts; for the grandeur and importance of the Nation being dependent on its military prowess, it was of consequence not to cherish any feeling or taste which could tend to soften the character of the citizens, or lead them to prefer a life of tranquillity to one of continual exertion and danger. Consequently it appears, in more than one instance, that those who dedicated themselves to such pursuits were ridiculed;* and it was not till about eighty-six years before Christ, that any disposition in their favour can be said to have discovered itself in Rome. Sylla had sacked Athens and demolished some of the principal Roman. monuments and Temples of Delphi, Epidaurus, and Elis, but he had also sent a great proportion of the spoil to Rome, and it would seem that the possession of the fine productions of Greece generated by degrees a feeling in the conquerors propitious to the advancement of Art in their own Country. The taste, once admitted, soon became a passion, and Verres particularly is celebrated for the avidity he showed in collecting all the most valuable monuments of Sculpture and Painting in Sicily. At this time (when Rome was becoming the asylum of those artists who could no longer live in Greece) flourished Pasiteles, a Sculptor of no mean ability, Arcesilas, Strongylion, celebrated particularly for his Amazon *Eucnemis*, or "with the beautiful legs," and his three Muses, Olympiosthenes, Evander, and others. The successes of Julius Cæsar Julius Cæsar. enabled him to add considerably to the collection of fine works of Art which were in Rome; in his more private condition he had always manifested a strong feeling for the elegant Arts, and had made valuable collections of statues, gems, &c.; when his power became fully established, his patronage of them became more extended, and he embellished not only Rome, but many cities of Gaul, Spain, Greece, and Asia Minor.

Augustus encouraged artists, and took the greatest Augustus. possible interest in their works; he had all the finest specimens of Art collected together in Rome, and placed them in the public places and streets of the city; he is also said to have erected statues in honour of those persons who had distinguished themselves by any important actions, or had otherwise deserved well of their Country. The fine statue called Germanicus, which is now in the Museum of the Louvre, is considered to be of this period. The example set by Augustus was followed by most of the rich in Rome, and as forming collections of Statues and Paintings became a passion amongst the higher classes, no expense was spared to gratify it. Pliny enumerates many of the works which were executed under the Emperor's superintendence, and various productions in Sculpture and Painting, with which the public places, Temples, &c. were decorated. Agrippa appears to have Agrippa. been one of the most munificent and public-spirited individuals of the Augustan Age, and he spent vast sums in erecting useful and ornamental edifices in and about Rome. Before other works, the Pantheon stands preeminent, and still calls forth the admiration of posterity as one of the finest examples of Architecture remaining to us. Diogenes, a Sculptor, an Athenian by birth, was employed by Agrippa to enrich this Temple; Pliny notices some statues of Caryatides by him. There were several artists of high reputation living during the Age of Augustus; the Architect Vitruvius, whose valuable writings have reached our times, is eminent amongst them; Dioscorides, Agathopus, Epitynchanus, Pythias, Posidonius, celebrated engravers on stones and sculptors or chasers in metal, may also be placed at this date, whose works are highly spoken of by Pliny: some of these have fortunately been preserved, by which posterity is enabled to judge of the ability of the artists who executed them. The works, however, of this period which claim the attention of the student and connoisseur, are principally portraits, in which great merit will be discovered; the difference between them and the productions of the best Greek Schools will be found to consist in certain peculiarities of execution. There

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* Val. Max. says of Fabius Pictor, *risu et contumeliâ erat.*

is, indeed, much to admire in the style of many of them; great attention seems to have been paid to the individual character of the person represented, and this without producing the poverty or littleness which too frequently offends the taste in works of this description.

The Toro Farnese.

The Laocoon.

The Cupid and Psyche.

Tiberius.

The group generally known as the *Toro Farnese*, to which allusion has been made in a former part of this Essay, has been attributed by some antiquaries to this period, or, at any rate, to the time of some of the early Roman Emperors. It will occupy too much space here to enter into a question which has already occasioned much discussion; Winckelman considered it early Greek, that is, before the time of Lysippus. This fine work, which has lately been removed from the gardens of the Villa Reale, at Naples, to the Museum there, has suffered very much from accident, and, unfortunately, the restorations which have been made are very inferior, both in style and execution, to the original work. The same date (the Augustan Age) has been given to the group of Laocoon and his sons; the manner in which Pliny speaks of it having, amongst other reasons, given occasion to some to think it was not ancient in his time. It must be observed, that this writer says it was formed out of one block of marble; a mistake which is evident to all who have examined this exquisite work, in which the joints of the various pieces are very perceptible. The Age of Lysippus also has been given as another probable time at which this group was executed, but the reasons adduced by the different antiquaries who have considered this subject in favour of the later date appear sufficiently well founded to claim the preference. One of the most beautiful and interesting groups of antiquity, "the Cupid and Psyche," at present in the Museum of the Capitol at Rome, is not noticed at all by Pliny; Flaxman considered that his silence might have been owing to his classing this as a modern work unentitled to notice, because it was not the production of any of those great masters who were looked on as the standards of excellence in his time; a reason which probably led him to pass over several other works which occupy a distinguished and well-deserved place in our estimation. A circumstance is related, which occurred during the reign of Tiberius, showing that the Roman people were not a little jealous of the fine works, which the liberality of individuals had erected or dedicated for the decoration of the city. Tiberius admired a celebrated statue, by Lysippus, representing an athlete anointing his limbs, and, desirous of possessing it, he had it removed from the Baths of Agrippa, in which it stood, (and to which the Public had access,) to his own Palace: this excited the indignation of the people, who refused to allow the Emperor to deprive them of it, and their dissatisfaction was so great, that it had nearly occasioned a revolt in the city. Tiberius, alarmed at the violent expression of public feeling, was obliged to relinquish his object; he ordered the favourite statue to be replaced in its original situation, and the people were pacified.

Caligula.

Caligula collected works of Art from Greece, but was influenced rather by a desire to gratify his own wretched ambition, than by any wish to possess them as beautiful works of Art, or interesting memorials of an enlightened people; he ordered the heads of the Gods and of illustrious men to be struck from their statues, and his own portrait to be introduced in their places. It is recorded that this Emperor wished to transport the celebrated statue of the Olympian Jupiter to Rome, but the design was abandoned on the representations of the Architects, who declared it would be destroyed in any attempt to remove it.

Nero.

The Apollo Belvidere, and the Fighting Gladiator. Plate IV. Fig. 2.

Claudius and Nero followed; the latter, notwithstanding what had already been taken from it, obtained no fewer than five hundred bronze statues from the Temple of Apollo, at Delphi, the greater part of which were employed in the decoration of his celebrated Golden Palace. Amongst the ruins of a Villa, or Palace, supposed to have belonged to Nero, at Antium, two of the most esteemed works of antiquity which have reached our times were discovered, namely, the Apollo of the Belvidere, and the Warrior of Agasias, commonly called the "Fighting Gladiator." The names of Menodorus* and Zenodorus, Sculptors, are distinguished during this period: the first was an Athenian, and is alluded to by Pliny for his skill in representing armed men, athletes, and huntsmen. Zenodorus executed many important works, but he is particularly mentioned as having made a colossal statue of Nero. This artist was practising Sculpture in Cisalpine Gaul, when Nero sent for him to Rome, but it is not known of what place he was a native.

The reigns of Galba, Otho, and Vitellius were too short and disturbed to give those Emperors an opportunity, even if they had the inclination, to protect the Arts; though, it is said, that Otho appropriated a considerable sum of money for the completion of Nero's Golden Palace. Busts of these three Emperors are extremely rare.

To this period, or soon after their time, are to be attributed the greater part of those works in Sculpture which are composed of different coloured marbles; productions in which the value or richness of the material was preferred to the merit or excellence of the design or execution—a sure indication of the existence of a false and bad taste, which was leading to the extinction of really fine Art.

Trajan.

Nothing further occurs worth noticing in the History of the Art till the time of Trajan, and the reign of that Emperor, of Hadrian, and the Antonines, may be considered the golden Age of Sculpture in Rome, though it is probable that the Art was but little practised by native artists even at this time. The arch at Ancona, and the column still existing in the Forum of Trajan at Rome, are monuments of the taste of the Emperor and the skill of the artists who were living during his reign. It is said that a custom prevailed at this time of putting Roman names on ancient Greek statues; it is not very easy to divine the object of this species of forgery, unless it were done with the hope of giving posterity a higher impression of the talent of the artists than they felt their own works were likely to create.

Hadrian.

In Hadrian, the Arts found a magnificent protector, and they maintained their excellence undiminished; he restored many of the old Temples, erected others, and amongst other important undertakings, completed the Temple of the Olympian Jupiter, at Athens, which had remained unfinished since the time of Pisistratus; he decorated it with a variety of works, and a statue of colossal dimensions of the Emperor himself was placed in it. In Italy, he built his celebrated Villa, and embellished it with all the finest works he could find of

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* There were, probably, two Sculptors of this name; *vid.* Paus. and Plin. for their works.

Sculpture.

and took Rome; in the year 456, Odoacer gave the city up to pillage; Genseric, King of the Vandals, almost rendered it a desert; and, in 545, the Goths, under Totila, again attacked it with brutal fury, and fired the city, which continued burning for several days. We are told that in this siege the Romans, having retired into the Mausoleum of Hadrian, (the present Castle of St. Angelo,) threw down the statues which decorated it, on their enemies under the walls.

In the year 479, a fire at Constantinople occasioned the destruction of an immense number of statues and other valuable works of Art collected in the Palace of the Lausi.

Justinian.

The Arts were again protected by Justinian, and this Emperor had several monuments of importance executed, amongst others a statue of himself, which was placed on a column decorated with *bassi rilievi*: the magnificent Church of Sancta Sophia, at Constantinople, was also erected during the reign of this Prince.

Constans, Emperor of the East, in the year 661, driven from his Capital by the imprecations of his people, visited Rome, which he despoiled, during the few days he remained in it, of its most valuable possessions in Art; these were removed by his orders to Syracuse, where he proposed to establish himself, and where he concluded his pilgrimage of disgrace and rapine. Wars, seditions, Political and Religious divisions, now fully occupied the public time and attention both in the Eastern and Western World, and gave no leisure for the protection of the Arts; on the contrary more frequently led to the destruction of those few monuments which remained. The successes of the Saracen Caliphs carried them into Sicily, and thus the objects collected there fell into the hands of new masters. The fury of the Iconoclasts and the conquests of Barbarians, tended still further to forward the work of destruction; occasionally, individuals appeared who were disposed to protect the remains of antiquity, and, as was the case with Charlemagne, and afterwards with Theodoric, to stop the ravages which were consequent upon the successes of their Barbarian followers: but their influence, honourable to themselves, was quite inadequate to effect their purpose, or to save the Arts, which were now hastening rapidly towards their final extinction. We still watch with interest the existence of some of the *chef-d'œuvres* of Sculpture preserved, amidst all the confusion and difficulties of the time, in Constantinople, to which remote corner of Europe the Roman name was at length reduced, the Empire of the West being now entirely at an end; but when Constantinople was taken by Baldwin, even these few remains were doomed to destruction, and the statues in metal were melted down and converted into money;* amongst them were a magnificent Juno, by Lysippus, a colossal Hercules, a statue of Helen, and a variety of other works, the productions of the most flourishing time, and most celebrated Sculptors of ancient Greece. We have purposely hastened over this portion of our account, for it is difficult and unsatisfactory to trace the further History of the Art, when each step we take but assures us of the ruin and devastation around us, and leads us in fact into darkness. The monuments of the Romans are very numerous, and have been of great assistance both in illustrating the writings of the Historians, and in making us acquainted with the manners and customs of that people; but, for obvious reasons, the History of their Sculpture has not the same claims on our interest or attention which we are disposed to give to that of Greece, and our observations on it have, therefore, been as compressed as possible. The History of ancient Sculpture may be considered to cease at this part of our Essay; in the next stage of our inquiry we shall commence that of Modern Sculpture.

A. D. 1204.

We have endeavoured in Plates I., II., III., IV., and V. to illustrate the progress of Sculpture from the earliest period to the time of Hadrian. Plates IV. and V. contain specimens from Myron, the contemporary of Phidias, about 500 B. C., down to the IId century B. C.: the best illustrations of the School of Phidias will be found in the British Museum. No certain date can be assigned to the Fighting Gladiator, the Laocoon, or the Group of Dirce in the above Plates, but of their School there can be no doubt.

Revival of Sculpture.

Though it is difficult to trace, in the specimens of rude Sculpture and bad Painting of the darker Ages, any resemblance to the works of a former period, it would still appear that the embers of the Arts of Design had been kept alive by the Monks of the Greek and Latin Churches, and were again kindled into a flame by the Italians, as soon as they found themselves in a state of comparative ease and security. It is true that from the Age of Constans to the XIIIth century, the productions of the early practitioners exhibit but uncouth representations of the same subjects, insomuch that it is almost impossible to decide with exactness on the time of their execution; indeed, it is probable that most of these were local and accidental efforts of uncultivated Barbarism, for which there was no general demand, but which gratified ignorant individuals or corporations, chiefly Ecclesiastical; and to this circumstance may be traced the uncouth decorations of some very old Churches and Tombs. In the illuminated MSS., executed in the richer Convents, a style of design was soon adopted, which depended on neat drawing and careful finishing, and became the business of ingenious and literary Monks when there was no other demand for Painting. The *orefici* (gold-workers) in Pisa and Florence, had, however, some encouragement in ornamental work, on a small scale, in gold and silver; but there was no demand for Sculpture in large masses of less costly materials; and the characteristic of their Art would naturally be minuteness, stiffness, and timidity of design. From the Bodies of artists in these trades the first successful efforts of Painting and Sculpture seem to have arisen; but it is easy to see in the predecessors and contemporaries of Giotto and Cimabue, that their Paintings on board are little more than enlarged imitations of illuminations on paper and vellum.

The discovery of oil-painting gave to artists the means of increasing the depths of their shadows, and, consequently the roundness and relief of their Pictures; it led them gradually to abandon the meagre style of the enlarged illuminators, and to approach that of Lionardo da Vinci, who may be considered the greatest master in the early manner. In its progress it was influential on Sculpture; and as both Arts were often exercised by the same individuals, it will be easily seen that in the composition of the bronze reliefs on the gates of the Bap-

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* Nicetus Choniates.

tistery, at Florence, (as well as in other works,) both Pisano and Ghiberti have adopted the design and arrangement peculiar to the sister Art, rather than the imitation of the antique models. This transfer of picturesque effect to Sculpture, gave a different character to the revived Art to that which it possessed in ancient times, and it unhappily became the source of much defect and corruptness of style; though it must be confessed that, in the hands of men of genius, it occasionally produced beauties of its own, which it is impossible not to admire in spite of the deviations from pure classical taste. This alliance with Painting is the grand characteristic of the works of the *Cinque Cento* artists and their successors. Among the Ancients, Sculpture seems almost to have given the laws of design and composition to Painting; their knowledge of perspective was limited, their power of representing shaded distances feeble, and their Pictures, in consequence, were treated much like *bassi rilievi* coloured. At the revival of Art, Painting soon became possessed of powers beyond the reach, but not beyond the emulation, of Sculpture, and it was vainly endeavoured to produce that, in marble, which can only please, and, indeed, can only be effected by colour; the hair, the draperies, the attempted gradations of perspective, in the works of all this School, bear witness to its failure. These observations have carried us further than we intended, but it is impossible, perhaps, to develope the actual nature of the progress of Sculpture during this period, without adverting to the contemporary progress of Painting, by which it was, to a certain extent, both guided and misled. To resume the history of the Art. In the beginning of the XIIIth century, Nicolo Pisano appeared; he was, as his name denotes, a native of Pisa, and is said to have improved his genius and feeling for his Art by the contemplation and study of some recently discovered ancient sarcophagi, &c., still existing in his native City.* Many of his works are preserved in different parts of Italy, and are evidence of the native power of his mind in general composition and feeling. Amongst the most remarkable are the pulpits of the Baptistery at Pisa, and of the Duomo of Siena, and particularly a semicircular *basso rilievo* of "the taking down from the Cross" over one of the entrances to the Duomo of Lucca. Besides these, Nicolo executed the principal part, and probably designed the whole, of the marble *alti* and *bassi rilievi* which decorate the front of the Cathedral of Orvieto: they consist of illustrations of the Old and New Testament, arranged in compartments; the figures in these are frequently ill-proportioned, the heads large, and deficient in expression or character, but the compositions are for the most part good, the draperies well understood and executed, and in the female figures and angels, particularly, there is a simplicity, grace, and feeling, which have rarely been surpassed. Nicolo lived to a great age, and was succeeded by his son Giovanni di Pisa, Arnolfo of Florence, and other scholars. In the year 1330, Andrea Pisano, who was settled in Florence, executed one of the bronze gates of the Baptistery in that city, a work which deserves attention for the beauty and simplicity of feeling it exhibits, though it is certainly deficient in the more mechanical excellences of Sculpture. With Andrea Pisano, was contemporary Andrea Orcagna, an artist of ability, who executed a variety of works, the greater part of which are still to be found in Florence. Luca della Robbia died in 1442; he has left several specimens of Sculpture. This Sculptor is well known as the inventor and only possessor of the Art of covering models of terra cotta with a beautiful and peculiar varnish, which renders them as hard as stone; he is supposed never to have disclosed this secret to any person, but it is said he committed it to writing, and enclosed it in some one of his models; whether this was the case can only be known by the destruction of his work. Amongst his productions are some of great beauty, both in feeling and composition.

Modern.

Luca della Robbia.

Ghiberti.

Donatello.

The next names which occur in the annals of modern Sculpture are those of Lorenzo Ghiberti and of Donato di Betto Bardi, better known as Donatello. The celebrated bronze gates of the Baptistery at Florence by Ghiberti have insured for that artist a lasting fame with posterity: this work consists of a series of *bassi rilievi* in the panels of the gates, illustrative of subjects of Scripture, and they contain passages of beauty, of feeling, and of expression, which far surpass any thing of the sort produced by his predecessors in the revival of the Arts, and have not been often excelled in the works of more advanced times. Donatello, one of the most deservedly celebrated of the early artists of Italy, was a scholar of Lorenzo di Bicci; he was born in Florence in the year 1383. The works of Donatello appear to have been highly prized during the lifetime of the artist, and though his principal employment was in his native city, we find specimens of his talent in many towns of the North of Italy. His most celebrated works are still to be seen at Florence; the two statues which are most noticed are those of St. George and St. Mark at Or San Michele: there is a simplicity of action and grandeur of expression in the former of these, which reminds the spectator strongly of the fierce and nervous manner characterising the works of the succeeding Age. The statue of St. Mark is distinguished by Michael Angiolo's celebrated exclamation, *Marco, pèrche non mi parli?* In the Museum at Florence are some very curious *bassi rilievi* by Donatello in marble: they represent groups of children dancing, composed with great skill; they are executed in very low relief, and the back-ground is covered with gold-leaf, put on in round pieces, each about the size of a guinea. At Padua are some specimens of *basso rilievo* of this Sculptor, which, making allowance always for the early time at which they were executed, well deserve the attention of the admirers of Art. It is probable that the somewhat exaggerated treatment which is observable in the works of Donatello, as well as those of Ghiberti, arose from a desire to avoid the dryness of their predecessors; and this will account for some peculiarities in the forced bendings of the wrists, fingers, and other articulations in their figures. The contemplation of the works of these two Sculptors, who made such rapid strides in Art, cannot fail to afford the highest satisfaction to all who feel an interest in watching the advancement of the refined pursuits of the human mind.

Anecdote of Donatello.

An anecdote is related by Vasari of Donatello and his friend Brunelleschi, who was afterwards the most celebrated Architect of his Age, which will not be read without interest in this place: we extract it from the valuable and well-known Work by Mr. Ottley on the *Italian School of Design.* "Donatello had recently made for the Church of S. Croce, at Florence, a crucifix carved in wood with extraordinary care; and proud of

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* They are preserved in the Campo Santo at Pisa.

his performance, showed it to his intimate friend Filippo Brunelleschi, in order to have his opinion; when Filippo, who, from the previous description of Donatello, had been prepared to expect a work of much greater excellence, did not wholly suppress a smile. This did not escape the notice of Donatello, and he conjured his visitor by all the ties of friendship to declare to him his real sentiments. Brunelleschi, who possessed great frankness of character, replied, 'that the figure he had placed upon the cross appeared that of a day-labourer, rather than a proper representation of Jesus Christ, whose person was of the greatest possible beauty, and who was in all respects the most perfect man that was ever born.' Donatello, already disappointed of the praise he had anticipated, could not brook the unexpected severity of this remark. 'It is easier to criticise than to execute,' he retorted; 'do you take a piece of wood, and make a better crucifix.' Brunelleschi said no more; but upon his return home, secretly went to work, and after the labour of several months, he finished a crucifix in the most perfect manner. This done, he invited Donatello one day, as if accidentally, to dine with him, and he having accepted the invitation, the two friends walked together towards the house of Brunelleschi, till they came to the old market-place, where the latter purchased various eatables, and giving them to Donatello, requested him to go on with them to the house, where he would join him presently. Donatello, therefore, having reached the apartment of his friend upon the ground-floor, had his attention immediately arrested by the crucifix of Brunelleschi, which that artist had taken care to place in an advantageous light; and standing before it, he became so absorbed in the contemplation of its superlative merits, as entirely to forget the provisions committed to his charge; for opening by degrees the hands which supported his apron, down came the eggs, cheese, and other things, upon the floor. Notwithstanding which, he still continued in the attitude of one overcome with admiration, until the arrival of Brunelleschi, who, laughing, asked him how they were to dine, now that he had spoiled every thing? 'I,' answered Donatello, 'have had quite dinner enough for this day. You, perhaps, may dine with better appetite. To you, I confess, belongs the power of carving the figure of Christ; to me, that of representing day-labourers.'"

Giovanni Pisano the Second.

Verrochio.

Rustici.

Donatello lived to a great age, and left numerous scholars; one of them, Giovanni di Pisa, was the author of a large *basso rilievo* in terra cotta, now in a chapel in the Church of the Eremitani at Padua: it represents the Madonna and infant Christ, and on each side of her are three figures of Saints. This work has some of the faults of the time, but it is an extraordinary production, and deserves attention for the simplicity and breadth of its composition, as well as for its execution; it is remarkable, too, for the very flat style of its relief, but it has all the breadth and effect which that mode of treatment insures, and which, united with elegance of form, calls forth our admiration in the celebrated frize of the Parthenon. Passing over names of less importance, though worthy of distinction if our limits would admit of it, we proceed to Andrea Verrochio, particularly celebrated as the master of Lionardo da Vinci and of Pietro Perugino, the master of Raffaelle. Verrochio was at first a painter, but it is said that Lionardo, when a lad, being desired to paint an angel in an altar-piece on which his master was employed, the performance of the scholar proved so superior to the rest of the work, that Verrochio, indignant at and jealous of being surpassed by a stripling, renounced the palette, and devoted himself to the sister Art. Some of the works of this artist are to be seen at Florence; particularly a group of two figures, Christ and St. Thomas, in Or San Michele, and some *bassi rilievi* in the Museum. Rustici, who studied under Verrochio, and subsequently under Lionardo da Vinci, was a native of Florence; this artist was invited into France by Francis I., where he died in 1550: amongst his works are several of classical subjects which have considerable merit.

XVth and XVIth cen- turies.

The situation and political circumstances of Italy at this time are peculiarly striking and deserve attention; for the XVth and beginning of the XVIth centuries comprehend a period of the greatest interest in the modern History of Science and the Fine Arts. The extraordinary talents of the Medici had raised that Family to the highest honours at Florence; and Lorenzo, who well merited the distinguished title he obtained of "The Magnificent," added to the lustre of his condition, by attaching to his Court the most ingenious and learned men of the Age. Rome, too, was governed by Pontiffs who, uniting magnificence with fine taste, extended their powerful protection to the Arts. Julius II., who assumed the tiara in 1503, gave princely encouragement to the great artists of his Age; he was succeeded by Leo X. and Clement VII., who, descended from the Family of Medici, felt an interest in the elegant Arts similar to that which had rendered Florence so famous: the names of these munificent patrons of genius and talent are identified with all that is valuable in Art, Science, and Literature.

Michael giolo Bu roti.

The powerful genius of Michael Angiolo Buonaroti gave a new impetus to Art, and placed that extraordinary man at once in the distinguished station which he still continues to occupy, and which no artist of his own or a later Age has been able to attain. Baudinelli, the Ammanati, Rustici, the Monte Lupi, Sansovino, Benvenuto Cellini, Giovanni di Bologna, Francavilla, who were all either living in his time, or formed out of his School, and have left great names, were but minor stars in the horizon in which he shone, and still shines, resplendent. Michael Angiolo Buonaroti was born of a noble family in Florence, in the year 1474, and at an early age became the scholar of Ghirlandajo, one of the most eminent painters of the time. Lorenzo de' Medici had established an Academy in his Gardens, and the genius of Michael Angiolo did not escape the notice of that Prince, who immediately gave him apartments in his palace, and otherwise honoured him with marks of particular favour. It will hardly be thought necessary to particularize the productions of an artist so well known as Michael Angiolo; but as our object is to illustrate the History of Sculpture, it will not be improper to point out some of his most celebrated works in this Art, for the purpose of comparing the peculiarities of his style with other monuments of his own Age, or of those artists who preceded him. Till this time, the works of the artists, since the revival of the Arts, were meagre and little in their details, though considerable feeling and talent were occasionally displayed in their conception, invention, and composition. Extraordinary genius, like that which distinguished Ghiberti and Donatello, occasionally broke through the dryness of the prevailing practice in some degree, but it was left to the gifted Florentine to effect that total revolution in style which has stamped the Art of his Age with a character peculiarly its own, which has been happily termed "*di Michel Agnol' la terribile via.*" The merits of Michael Angiolo have been too frequently insisted upon to need any detailed consideration here; we shall content ourselves therefore with pointing out to our readers the most striking of his excellences, noticing afterwards in what he appears most deficient as a Sculptor. For this purpose it will not be necessary to notice his works in the order in which they were executed; we shall begin therefore with the well-known monuments in the Chapel of the Medici at Florence, in memory of Giuliano and Lorenzo, (not "*il magnifico*,") two members of that family. The statue of the latter is most remarkable for its character and expression: Lorenzo is represented seated and wrapt in thought; he leans his face on one hand, which partially covers the chin and mouth; the rest of the figure is in perfect repose, and throughout the whole there is the air of deep meditation. It is impossible to look at this statue without being forcibly struck with the *mind* that pervades it. For deep and intense feeling it is certainly one of the finest works extant.[*] The lower part of this monument consists of two statues intended to represent Morning and Evening, which form a strong contrast to the dignity and simplicity of the figure above them; they are grandly conceived and boldly executed, but there is a violence of action in them which is completely at variance with the repose of the pensive statue of Lorenzo, and which seems to have been adopted rather for the purpose of exhibiting anatomical knowledge and manual skill, than of adding to the real interest of the design. The monument of Giuliano is composed on the same principle; the two figures beneath the principal statue are those of Day and Night, and although they bear the stamp of the master hand, they want all that quiet which is not only essential to the beauty of Sculpture, but which seems to belong particularly to the subject on which they are employed. The statue of Moses in the Church of S. Pietro in Vincoli, in Rome, is one of the most celebrated works in Sculpture of Michael Angiolo, and is a grand effort of skill. The admiration which this statue excites is caused chiefly by the principles of composition which are employed in it; no small parts nor acute angles distract the attention, but quantity and large masses are preserved throughout; in the general expression there is vast energy, but it is sufficiently tempered to preserve that repose which is essential to dignity. This work requires to be studied with attention to be understood; its merits will then be found to compensate for minor faults, which the *manner* of Michael Angiolo threw more or less into most of the productions of his chisel or pencil. The statue of Christ, in the Minerva Church at Rome, has less of the violence of this master than most of his works; but, although it has excellences of a high class, it is by no means one of his finest efforts; it displays great learning and skill in execution, but it wants that dignity and refinement of form and expression which should characterise the representation of the Saviour of the World. An allegorical *basso rilievo* preserved in the Vatican, (and of which there are casts,) is an interesting monument of Michael Angiolo's knowledge of the human form; it is more remarkable for this than for any other quality; the composition being too complicated to render it unexceptionable as a work of Sculpture. The statue of David, in the Piazza del Gran Duca, at Florence, was executed under very unfavourable circumstances, Michael Angiolo having been employed to finish it when the block of marble had already been worked upon by an inferior artist, and considered spoiled; but the powerful hand of the master is visible, and few can look upon this work without being struck with the grand air it has as a whole, and particularly with the turn and expression of the head and throat. The statue of Bacchus is admirable for its expression of inebriety, and for the execution, but it wants purity of taste, and the beautiful form which the Ancients always considered proper to the young and joyous God. The group in marble of the Madonna and Child in the Chapel of the Medici at Florence, the Pietà in St. Peter's at Rome, and the unfinished group of the Body of Christ supported by Nicodemus, the Madonna, and Mary Magdalen, are compositions of the highest merit, abounding in pathos, and many excellences of execution: the dead Christ in the Pietà is particularly worthy attention; the tranquillity and perfect repose of death is finely portrayed throughout this figure, and, with some exceptions to the head, and articulations of the joints, it is free from the *manner*, as it is called, which is generally so conspicuous in Michael Angiolo's Sculpture. We would notice, too, a work which we possess in England by this great master, abounding in grace and feeling; it is a circular *basso riliero* in marble, consisting of three figures finely composed, representing the Virgin, the Infant Saviour, and St. John, and which, though unfinished, is a beautiful and highly valuable example of the artist.[*]

In contemplating the works of Michael Angiolo, the spectator is so completely absorbed in admiration of the invention, vigour and energy of mind, and vast knowledge of form and anatomy displayed in them, that he hardly allows himself to think they can be wanting in any other qualities of Art. But it is an undeniable fact that Michael Angiolo's Sculpture does not afford that high satisfaction which works of ancient, and some even of modern times occasion; and we are naturally led to inquire the cause of this, in an artist whose reputation stands so high, and the productions of whose pencil still fearlessly defy competition. Sculpture, to be perfect, must be practised on certain principles, and, without them, whatever other qualities it may possess, it has not the power to please, nor to make any lasting impression on the mind. The chief of these essential properties is simplicity. This it is which gives a charm the productions of Greece, and to the best works of a later Age, and it is to the absence of this, that we must attribute the little effect produced by the generality of modern works; amongst them by many of those by Michael Angiolo. All who have seen it remember with feelings of satisfaction his "*thinking*" statue of Lorenzo de Medici; it comes home to every heart; it is Nature, but in character and expression dignified by the highest power of Imagination. Few recollect more of the statues of Morning, Evening, Day, and Night, than their attitudes; the affections and feelings have little or nothing in common with them, and their want of simplicity dis-

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[*] It has been well and justly observed of this statue, "There is no resemblance to the antique, but it rivals the best excellences of the Ancients in expression with repose and dignity; *such effects are produced by the study of real life contemplated by genius and imagination.*"

[*] This work was purchased in Rome by the late Sir George Beaumont, Bart., and bequeathed by him to the Royal Academy, where it is now preserved.

tracts rather than interests the attention. It has been our duty in these few observations to consider the Sculpture of Michael Angiolo with reference to its merits compared with that of the Ancients; for he made gigantic strides which placed him, beyond comparison, far above any of his contemporaries. We have only had to consider him as a Sculptor, but in giving him the distinguished rank his high and extraordinary merits claim for him, it has been thought necessary to notice what his Sculpture wanted to place it on a level with the finest productions in that Art.

In the Chigi Chapel in the Church of S. Maria del Popolo, at Rome, is a group in marble of Jonas with the sea monster, which is believed to be a production of the time which we are now considering. It is a work of great beauty, and it is to be regretted that its situation is such as to preclude the possibility of viewing it to advantage: **Lorenzetto.** it is said to be the production of Lorenzetto, but if the tradition may be believed, Raffaelle d'Urbino furnished the design for it, and even made the model from which the Sculptor afterwards executed the marble. **Beggarelli of Modena.** About this time also lived Beggarelli of Modena, famous for his models in clay; concerning whom a remarkable expression of Michael Angiolo is recorded; he exclaimed, on seeing some of this artist's works, "If this clay could but become marble, woe to the antique statues." **Sansovino.** Tatti, better known as Sansovino, appeared at this time; several of his productions, statues, and *bassi relievi*, in marble and bronze, are preserved at Venice and Padua, and although they want simplicity, they display considerable talent; his scholars were numerous, and some of them, particularly Danese Cattaneo, Ammanati, Lombardi, and Vittoria, distinguished themselves by the success with which they practised their Art. **Baccio Bandinelli. Plate VII.** Baccio Bandinelli was a native of Florence, and takes a high rank amongst the artists of this Age; he was the scholar of Rustici, the intimate friend of Leonardo da Vinci, a connection from which Bandinelli must have derived great advantage. His style was very bold, his general designing vigorous, and his works display considerable knowledge of form; but his drawing is too free, and abounds in the *mannerism* which characterises the Art of this time. Several works in Sculpture by Bandinelli exist in Florence, which, though they do not place him on a level with Michael Angiolo, to whom he was always opposed, attest the skill of the artist. Amongst his most highly esteemed productions may be reckoned a number of figures in compartments, in very low *rilievo*, which decorate the base of the screen round the high altar in the Duomo of Florence; a *basso rilievo* in marble on a pedestal which stands in the Place of S. Lorenzo, also at Florence; which though in many respects open to criticism, has high claims to distinction, and may be considered a fair illustration of the Art of the Age. He made a portrait of himself in the statue of Nicodemus supporting Christ; (a group in marble, the size of Nature, for his own monument in the church of the Annunziata at Florence;) and in the Palazzo Vecchio are statues of Adam and Eve with the Tree and Serpent between them: the former of these works is superior to the last mentioned, but both are inferior to those before noticed. Baccio Bandinelli, either from his lofty pretensions, or the jealousy of his disposition, of which many instances are mentioned by Vasari, appears to have been exceedingly unpopular during his lifetime, and his works were severely satirized by his contemporaries; the sting of these remarks has however passed away, and his works remain to claim for him the distinction to which his merits as an artist entitle him. **Benven Cellini. Plate VII.** Benvenuto Cellini has a double claim upon posterity as a Sculptor and a writer. The estimation in which his smaller works were held, is attested by their numbers, and the high prices he obtained for them; most of these, from the value of the materials in which they were executed, gold, silver, and precious stones, have disappeared in the disturbances that have agitated Italy; but some of his larger works remain, and his Perseus, in the Loggia of the Piazza del Gran Duca, at Florence, particularly claims attention for the general conception of the subject, and the knowledge it displays. Faults no doubt may be found in it, but this work places Cellini amongst the most distinguished artists of his Age. His Life, written by himself, is one of the most curious histories of the manners of the XVIth century which we possess; he also wrote on casting in metal. **Properti da Rosi.** Propertia da Rossi, of Bologna, executed amongst other works some statues for the façade of the Church of S. Petronio, at Bologna; she also painted well, and was a good engraver. Propertia, it is said, became enamoured of a young artist who did not make a suitable return to her love, and the disappointment threw her into a languishing disorder which brought her to her grave; her last production was a *basso rilievo* in marble, preserved at Bologna, representing the history of Joseph and the wife of Potiphar, in which the object of her love was represented as Joseph, and in the other figure she portrayed herself. She is said to have been one of the most beautiful as well as accomplished women of her time, and died in the flower of her age.* **Guglielm della Por Sebastia del Piom** Guglielmo della Porta, the friend of Michael Angiolo and of Sebastian del Piombo, is celebrated for his restorations, particularly of the legs of the Farnese Hercules, and for two recumbent statues, one of Prudence, the other of Justice, forming part of the monument of Paul III. in St. Peter's at Rome. The latter figure has parts of considerable beauty, and is a valuable specimen of Art of that period; reminding the spectator strongly of the style of Michael Angiolo. Since Della Porta's time, this statue has been partially covered with bronze drapery.

The quality for which the Sculptors at the end of the XVIth and beginning of the XVIIth centuries are remarkable is, extreme facility of execution, which led them to lose sight altogether of repose and simplicity; the works of that time exhibit very great merit in many respects, but they abound with affectation and exaggeration; the first owing to a mistaken notion of grace, the other to a desire of showing science in the anatomy of their figures. **Gio di Bolog Plate** The works of Giovanni di Bologna, a native of Douai, are a remarkable illustration of this state of the Art; they are full of imagination and fire, and are executed with astonishing boldness and ability; his diligence as well as his skill is attested in the vast number of works which he has left in marble and bronze. The famous bronze statue of Mercury by him, in the Gallery at Florence, is conceived in the true spirit of Poetry, and is deservedly admired as one of the most elegant productions of modern Art; the form is light, and the action graceful; the only fault in this otherwise beautiful work is, that the muscles are rather too round for the character of the Messenger of the Gods. The celebrated marble group in the Loggia, at

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* Vasari. She died in 1530.

Florence, called the Rape of the Sabines, affords further illustration of what we have said respecting the style of Art of this time; as a specimen of invention it is full of fire and expression, but the composition partakes too much of the *corkscrew* form, and is extravagant; it is impossible, however, not to admire the courage as well as ability of the artist who ventured to execute so daring a work. Other statues and several *bassi rilievi* exhibit in like manner the power of mind and hand, but at the same time the defects of style, of Giovanni di Bologna. Unfortunately the imitators of his "manner" were numerous. The beautiful and simple figure of S. Cecilia in the Church of the Convent dedicated to that Saint in Rome, would place its author Stefano Maderno in the very highest rank, if he had not forfeited his claim to the distinction by the production of later works in which all the finer qualities of Art are lost sight of. This statue was executed when he was very young, probably before his taste had become corrupted, and its excellence arises from its simplicity and general truth to Nature. It is said, that when the coffin, in which the Virgin Saint was deposited after her martyrdom, was discovered, her body was found undecayed, and lying in the position in which Stefano Maderno, by order of Clement VIII., has here represented it.* This will account for the superiority of this work over others of the same artist; prevented by the circumstances from introducing any of the prevailing bad taste of the time, he has, by making Nature his model, produced a work which excites the sympathy and engages the suffrages of all who see it.

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One of the most extraordinary artists of the XVIIth century, and one whose practice tended more than any thing not only to check but to subvert all good taste in Sculpture, was Bernini. He was born at Naples, and at a very early age gave indications of talent in the Fine Arts; a head in marble is still preserved which he is said to have executed at nine or ten years of age. It is quite surprising, that, with so many fine works of antiquity before them, the admirers of Art should have so extensively patronised a Sculptor who set all the principles of true taste completely at defiance, and whose influence was so great that no Art was protected which was not conformable to that which he had established. Under him the distinctive bounds of the different classes of Art were trampled down; Sculptors were busied in imitating the works of the pencil, and Architects in seeking to introduce into their compositions the curved line of beauty. It would, indeed, be difficult to conceive two styles more directly opposed to each other than that which characterised the Sculpture of this Age, and that of the great artists of antiquity. In the one, simplicity was the pervading principle and expression united with fine form; in the other the eye is offended by strained actions, uncommon arrangement in composition, and draperies flying and frittered away. Undercutting, perforations, and all the other mere mechanical difficulties of the Art were also resorted to, to catch the attention and create surprise; thus the means were mistaken for the end, and the artists were content to rest their claim to distinction on the poor foundation of their ingenuity as handicraftsmen. A few artists may be selected from this large class, possessing qualities which raise them some little above their contemporaries, but in these the great principle which should pervade all Sculpture is lost sight of, and the picturesque is everywhere substituted for simplicity; indeed the *alti* and *bassi rilievi* of the best of the artists of this time are but bad pictures done in marble, on no part of which can the eye rest with satisfaction. The works of Bernini are too well known to require particular notice; we shall content ourselves, therefore, with mentioning a few of the most celebrated, to illustrate our observations on the merits and defects of this artist. Two of his best, and they were two of his earliest productions, are in the Cascino of the Villa Borghese, at Rome; *viz.* the Apollo and Daphne, and David, (said to be a portrait of himself,) preparing to throw the stone at Goliath. These figures display great feeling for the respective subjects, and equal skill in the execution, and only want good taste to entitle them to a very high rank in Sculpture. The statue of S. Bibiana, the fountain in the Piazza Navona, the four Doctors of the Church supporting the chair of St. Peter, are all characteristic works of this artist. In St. Peter's, also, are the monuments of Urban VIII. and of Alexander VII., which surpass all his other productions in bad taste. A group, intended to represent the ecstasy of S. Teresa, in the Church of La Vittoria, in Rome, has merits of execution, but it is difficult, amidst the flutter and confusion of the drapery, to discover either the figure of the Saint, or the subject of the work. Bernini lived during nine Pontificates: no artist ever had greater patronage, and few greater talents, had they been properly applied; but the variety of his pursuits, and his inordinate love of picturesque effect, ruined the progress of Sculpture, and we are compelled to admit, that it would have been better for that Art if Bernini had never lived. In proof of the versatility of his talents, mention is made of a theatrical entertainment which had been given in Rome by him, for which he built the theatre, painted the scenes, cast the statues, constructed the engines, wrote the comedy, and composed the music. We could easily extend our observations on this extraordinary man, but our object, that of illustrating the History of Sculpture, is sufficiently answered by noticing a few of the leading Sculptors, and making some observations at the same time on the peculiarities which mark their practice, and the improvement or decline of the Art.

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Plate VII.

Algardi.

Contemporary with Bernini was Alessandro Algardi, of Bologna, whose principal work, a large *basso rilievo*, in marble, of Attila driven from Rome by the apparition of St. Peter and St. Paul, is well known. This work is above 30 feet high, and 18 feet wide, and forms an altar-piece in St. Peter's Church. The observations which apply to the works of Bernini are equally applicable to those of Algardi, who, if he did not servilely copy the faults of the first-named Sculptor, was equally distant with him from the purity of the antique; in the *basso rilievo* alluded to, an attempt is made to obtain distance and picturesque effect by a variety of planes, and difference in the degrees of relief of the figures. The consequence is inevitable in Sculpture: it is a mass of confusion. Considerable intelligence is shown in parts of the composition, as well as in the execution of the work, but a principle of bad taste pervades the whole, which is not compensated by any other qualities. In short,

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* Venuti says, *nella positura medesima che si vede la sua statua scolpita.* The inscription under the statue is, *En tibi sanctissimæ virginis Ceciliæ imaginem quam ipse integram in sepulchro jacentem vidi, eandem tibi prorsus eodem corporis situ hoc marmore expressi.*

Il Fiammingo.

Mocchi.

Plate VII.

the Art instead of rising was now fast falling to decay; the very facility of execution, which should have been the means of carrying it to a second perfection, equal to the best times of Greek Sculpture, only hurried it to its ruin, and to the artists of the XVIIth century we must, in a great degree, attribute the disgrace of its downfal. One Sculptor, however, who lived at this period, deserves to be distinctly mentioned, inasmuch as he did not suffer himself to be carried away by the prevailing false taste, with similar facility to that with which the generality of artists bowed to its influence; this was Fr. de Quesnoy, commonly called Il Fiammingo, a native of Brussels, who, although his taste was far from correct, has left a few works which secure him a respectable name with posterity. His statues of Sta. Susanna, and of St. Andrew, at Rome, in St. Peter's Church, as well as his *bassi rilievi* of children, have passages of great merit, and claim the attention of all admirers of Art. Francesco Mocchi executed two statues in the Duomo of Orvieto, representing the Annunciation; they are not grouped together but are distinct figures. The angel has been much overrated, the boldness of the conception and execution having excited greater admiration than the general merits of the work warrant. The figure is supported on a cloud, which rests on the pedestal. The Virgin is gently shrinking and starting back; the intention is good, but the figure is short and heavy, and has none of that beauty of form proper to the subject. But little advantage will be gained by enumerating the works of the Rusconi and others of the same School, which only tend to illustrate the further decline of Sculpture. The minute and laborious works of San Martino and Corradini, in the Church of St. Severo, at Naples, representing the dead body of Christ covered with drapery, Modesty veiled, and a figure of Deceit within a net, attest the patience of their respective authors, and remain monuments of their bad taste. The same may be said, with few exceptions, of the works of the Bonazzi, Tagliapietra, Toretti, and Morlaiter, at Venice, and an infinity of other Sculptors, who deluged the different cities of Italy with absurd productions of their misplaced ingenuity.

Sculpture in France.

This was the state of Art in the XVIIIth century; and the taste which pervaded Italy was the prevailing taste in other Countries in which Sculpture was practised, the artists of Italy being almost exclusively employed to execute whatever works were required; or if native artists were anywhere thought worthy of confidence, they were for the most part scholars or followers of some distinguished or fashionable Italian practitioner. That this was the case in France will be evident on examining most of the Sculpture produced there from the time of Francis I.; the epoch from which the practice of the Art, and of its assuming any importance in that Country, is generally dated; and at which time Italian artists, Lionardo da Vinci, Primaticcio, Benvenuto Cellini, Rustici, and others were invited into that Country. The French Sculptors who arose out of this encouragement of Art, exerted themselves, it is true, with industry and success, and several have left distinguished names and valuable specimens of their abilities. A History of the French School of Sculpture* will not afford any additional information on the general History of Art, but from their most celebrated names we gladly select such as Puget and Girardon.

In England.

Henry III.

Edward I.

Edward III.

Henry VII.

Charles I.

We possess some very early specimens of Sculpture in England. Those who returned from the Crusades made attempts to imitate the Arts and magnificence of the Countries they had visited, and introduced some richness of decoration into the Architecture of their time; but no Sculpture in figures is deserving of particular notice till the reign of Henry III., when efforts were made in that Art not unworthy our attention even at the present day. In the year 1242, the Cathedral of Wells was finished under the care and superintendence of Bishop Joceline. This was about the time of the birth of Cimabue, the restorer of Painting in Italy, and the work was in progress at the same time that Niccolo Pisano, one of the earliest Sculptors after the revival of the Arts, was exercising his profession in his own Country. The circumstance is remarkable, and the late lamented Professor of Sculpture in our Royal Academy adduces strong arguments for believing the execution of the *bassi rilievi* and statues which decorate this structure to have been by native artists.* These Sculptures, consisting of subjects from the Scriptures, and some statues, larger than life, of our early Kings and Queens, exhibit much grace, beauty, and simplicity, and, making allowance always for the time at which they were executed, are well worthy the attention of the curious. The richly decorated crosses erected by Edward I., in those places wherein the body of Queen Eleanor rested, (and of which three are still remaining,) were most probably by Italian artists; but under Edward III. it seems that our own Countrymen were capable of exercising the Art. To use the words of Flaxman, "it is a gratification to know that the principal Sculptors and Painters employed by Edward III. in his Collegiate Church, (St. Stephen's,) now the House of Commons, were Englishmen;" and he gives us the names of Michael the Sculptor, Master Walter, John of Sonnington, John of Carlisle, and Roger of Winchester, Painters. Passing on to the reign of Henry VII., we find that Torregiano, an Italian artist of some celebrity, was much employed in England in the beautiful Chapel built in Westminster Abbey; but it is thought that much of the Sculpture of this period was by native artists. It will be sufficient to refer the curious reader to some of the statues that decorate the above Chapel, which are well worthy attention for the beautiful and simple arrangement of their draperies. From the reign of Henry VIII. to that of Charles I. Sculpture seems to have been much neglected; indeed works of Art were wantonly and purposely destroyed; but from the wrecks that remain it appears that from the year 1200 down to Henry VII., we have works in Sculpture, not only executed in England, but certainly in many very important instances by Englishmen. In Charles's time we meet with the names of Christmas and Stone, Englishmen. The principal works in Sculpture after this period were by foreigners, and we find that Cibber, Scheemacker, Roubiliac, and others of their School, had all the employment in Art. Their productions are well known, and a particular account of them

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* The French (though a great improvement has taken place) were soon led away by a desire to display nice and curious execution; the Sculptors above named were their purest artists. For the *ne plus ultra* of bad taste we need only mention Pigal's extraordinary works, particularly the Tomb of Marshal Saxe, at Strasburg, executed in 1776. The Sculpture of other European Countries, Spain, Germany, &c., affords no information on the History of the Art, and we therefore omit them.

* *Vide* Flaxman's *Lectures on Sculpture.*

would be both unnecessary and out of place. This was the state of Art in England till the middle of the last century, when, under the protection and auspices of George III., Sculpture and the sister Arts rose into notice, and were practised by native artists with honour to themselves and to their Country.

The Count Cicognara, in his valuable Work on Sculpture, considers that the epoch of a revolution in taste in Italy was the reign of Charles III. of Naples; of Popes Clement XIII., Benedict XIV., and of Leopold, Grand Duke of Tuscany. Besides these Princes, Cardinal Albani, justly called the Hadrian of his Age, attached the literati and best artists of the day to him, and his Palace was the resort of genius, taste, and learning. He formed a collection of the finest remains of antiquity, well calculated to remodel the taste, and excite the emulation of the artists of the time. To this princely taste of the Cardinal the World is indebted also for the learned labours of a distinguished antiquary, for under the immediate protection of the Prelate, Winckelman wrote his *History of the Arts of Design.* The Clementine Museum at the Vatican received important additions under Pius VI., after whom it was called Pio-Clementino; and the greatest activity prevailed at his accession throughout the Roman States to secure whatever fine works in Sculpture were discovered, forming a remarkable contrast to the carelessness which existed on these subjects a few years before. Amongst the Sculptors of that period were Cavaceppi, Penna, and a few others; the influence of the Bernini School had ceased, and as the false principles of its practice were discovered, the want of a just style was felt, and, in point of fact, Sculpture in the hands of the above artists will be found to have made considerable approach to purity, and to have acquired much of its lost character.

The honour, however, of giving a new direction to Taste, and of establishing this Art on true principles, is certainly due to Flaxman and Canova; and the works of Banks may also be cited as valuable specimens of improvement. In the Theseus of Canova, one of his best and earliest works, we recognise the long lost purity of form, and a decided devotion to the simplicity of the antique; in the designs of Flaxman, in like manner, simplicity, grace, and expression resume their influence in the place of long-established affectation and distortion. The simple taste of which the earlier works of Canova gave promise, it must be allowed, is occasionally less conspicuous in some of the later productions of this master: exceptions will also be made to Flaxman, in whose works execution will be found a very secondary object compared with design; but the works of these distinguished artists are before the World, and their merits have been too often discussed to render it necessary here to enlarge upon them; besides, a critical examination of them would be quite out of place, our object, that of tracing the History of Sculpture down to our own times, being fulfilled. The influence of these second restorers of Sculpture, as they may justly be called, on the Art of their day is acknowledged, and though distinct Schools have arisen out of those which they formed, to them must be attributed the merit of having at least directed the attention of artists and the admirers of Art to that which is really excellent.

Mechanism of Sculpture

The mechanical process of Sculpture is now so generally known, that it seems hardly necessary to notice it here, but as it may be considered to form a part of our subject, we shall conclude by a short explanation of the manner of proceeding. The Sculptor having invented or conceived his subject, proceeds from a small sketch, drawn on paper or modelled in clay or wax, to build up his statue or group, for which purpose a general nucleus or skeleton is first formed of wood or iron; to this, small crosses are generally attached, in order to make the clay adhere to it; the figure is then built up in clay, of which different sorts are used, according to the fancy of artists; the figures, even if they are intended to be draped, should always be first carefully modelled naked, and the drapery should be added afterwards. In modelling *alto* or *basso rilievo*, a plane or ground (generally of clay) is prepared, upon which the Sculptor draws his proposed design; the clay is then placed upon this, the outline of the figures being carefully preserved by attending to the drawing already made upon the surface. The model being completed, and kept moist, a mould of plaster of Paris is made upon it, which when dry (or *set*) is removed, and the model is destroyed; the mould being oiled, is then filled up with fresh plaster, which is prevented from adhering too firmly by the oily substance with which it has been saturated; the mould is then broken off, and a cast of the model is produced entire. The next process is copying it in marble; for this purpose two stones of the same size, each having a scale in front, are prepared; the model is placed upon one of these, the block of marble on the other; a movable instrument or beam is applied to the scale of the model, and a needle branching from it, and capable of being extended and withdrawn at pleasure by means of screws and ball and socket joints, is made to touch the particular part of the model intended to be copied;* this is carefully removed to the corresponding number on the scale on which the rude block is fixed, and the marble is cut away till the needle reaches as far into the block as it had been fixed at upon the model; this process is repeated till the whole is copied, the joints on which the needle works being so constructed that it can be carried round to any part of the work. The statue being thus rudely blocked out, or pointed, as it is technically termed, is delivered over to a carver, who copies the minute parts of the work, and by degrees, with chisels and files, brings it to a surface, ready to receive the finishing strokes of the Sculptor.

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* The construction of these instruments for pointing is not always the same, but the principle upon which they act is exactly similar.

PAINTING.

HISTORY OF THE ART.

HISTORY OF ANCIENT ART.

Origin of Painting.

To renew that inqufry of the over-curious, as to the country wherein the Art of Painting was first invented, is nearly as absurd as to raise a question with regard to the persons who may have originated the Art of dressing skins or cooking meat, or introduced any of the commonest occupations of life; so natural is imitative Art to man, and so common is it to find some efforts in this line even among the rudest people, and those who are the farthest removed from the chance of intercourse one with another. We shall only observe, then, generally, that the extreme antiquity of this Art is fully shown, when it is admitted as a fact, that the use of representation by outlines, imitating the external forms of things, preceded the use of arbitrary and conventional signs amongst Mankind. Hieroglyphics were used before Letters, and the Art of Drawing is therefore undoubtedly prior to that of Writing; and we might fairly substitute this simple statement for the more common and fabulous part of its History. Of the fact we have proof enough in the painted and engraven monuments of Egypt, Persia, and India, as well as in the stained leather of the savages of the Ohio and the Mississipi, who relate a battle by figures of men fallen and falling, just after the same fashion. Very forcibly indeed are these ancient and primitive, and necessary habits of the human race brought before our eyes, in the accounts we daily receive of those uncivilized nations, among whom we view Man as a social animal during the time that the state of society is in its infancy.

Raphael Mengs remarks with great truth, that it might have happened that the Art of design was invented at the same time in Greece, Egypt, and in Tuscany, or that some of these people, of whom Historians speak as inventors, did themselves receive the Art from others who practised it before their day; but, after what has been observed above, this is of little consequence. We must consider, therefore, the stories related by ancient authors, as to the invention of the Arts of Painting and Statuary, not as relating actually to the first discoverer, but to that person of whose successful efforts the earliest tradition has been preserved,—to the improver, rather than the originator. Such was Gyges, a native of Lydia, who, as Pliny informs us, was a teacher of the Art of Painting amongst his countrymen in Asia Minor; and by whom the practice was afterwards carried into Italy by a colony from those parts, known under the name of the *Hetrusci* or Tuscans. Of the degree of skill possessed by these Hetrurians, some writers have asserted, that specimens may yet be seen in the painted figures discovered in the tomb of an ancient monarch, on the site of *Clusium*, and in some similar relics at Arezzo and Viterbo.

School of the Ancients.

In a like view must we regard the stories of the love-sick girl tracing the shadow of her suitor's profile on the wall, by the light of a lamp, or of the shepherds marking with their crooks the outline of their shadows, projected by the sunshine upon the sand. Such, too, are the claims usually put forward on the part of the Egyptians to the invention of the Art of design; that people probably were inventors, as many other people were so; but only among themselves, and for themselves. And no doubt there were attempts made by other countries as well as these, and perhaps at as early a date: we certainly read of Pictures being in use amongst the inhabitants of the land of Canaan, at the time that the Israelites took possession of it; the words in our translation of the Bible, in which Moses addresses the Israelites, are these, "destroy all their Pictures, and destroy all their molten images.' *Exod.* xxxiii. 52. And whether borrowed from Egypt or otherwise, it is clear that the Art of design was not unknown amongst the Jews themselves, either as Statuaries or Painters: for we read of the image of a calf set up by them in Dan; and we read in the prophet Ezekiel, of the "form of creeping things," &c. "portrayed upon the wall." *Ezekiel*, viii. 10.

All that is here mentioned under the name of Picture or Painting was probably no more than a simple delineation of form, the interior of which was occasionally filled up with colour; such as the earliest specimens of Egyptian Art present to our view; the capacity of executing such matters in such sort, being, as we have said, natural to Man as an imitative animal.

Its prog

The further developement of the Art of Painting, of that, indeed, which alone gives it a title to the name of Art, has been to a certain extent detailed to us by the ancient writers of Natural or Civil History. And the successive degrees of improvement which were achieved in these early days, afford to our contemplation a curious analysis of the nature of those ideas relative to Painting, which in the present more advanced state of our knowledge appear so simple in themselves, and to need so little elucidation. In our HISTORICAL and BIOGRAPHICAL DIVISION, we have already stated a few particulars relative to some of the Early Painters of Greece, (vol. ix. p. 404.) Without repeating what has there been said, we shall here notice the several steps by which they appear to have advanced the Art of Painting. One of the first instances of the progress of this Art is shown in the attempt to give a greater durability to the colours than had hitherto been attained. *Polygnotus*, (the elder of that name,) an Athenian, is said to have been the first who subjected his works to the action of fire for this purpose: but it is uncertain whether it was the encaustic method, the mode of Painting in enamel, which he invented; or, whether it was simply that he first adopted the use of wax with his colours, which of course could not be applied without some degree of heat; or it may be, that he merely invented the style of delineating by means of burning the surface

Use o by Po gnotu

of wood with hot irons, producing something similar to that which we now know under the name of *poker drawings*. Polygnotus lived about the XIVth century before our Saviour.

ochro- ic style, Chiaro- uro.

The next step in Art was made, as we are told, by the Greeks, who invented what is called the Monochromatic style or the use of a single colour, or that which we now describe under the title of Painting in *chiaro-oscuro*. It might be black and white that was made use of for this purpose, or a brown or a gray colour, or indeed any other, so long as the difference of the parts was marked only by the intensity or strength of the respective shades of colour, not by a variety of colours. It may seem singular at first sight, that the use of many colours should have preceded the simple use of one colour only: but when we regard the nature of the means by which an effect is to be produced, we must instantly recognise the proof of a greater progress in Art having been made in this case than the former; for to paint trees as green, or sky as blue, is one of the easiest and most obvious of the efforts of imitation, but to distinguish them by degree of shade alone, or, which is the same thing, by the intensity of the colour, when one only is employed, requires no small degree of knowledge and skill: it is, in fact, the power of giving relief to one body beyond another, and representing on one even plane surface the appearance of a variety of objects or parts which stand out or recede one from the other.

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We have an account given us by Cheselden, of a young man originally born blind, and afterwards receiving his sight from the operation of couching, at a time when his judgment was sufficiently advanced to give an account of his observations; namely, at the age of thirteen years. He says, "we thought he soon knew what Pictures represented, which were shown to him, but we found afterwards we were mistaken; for about *two months after* he was couched, he *discovered* at once they represented *solid bodies*, when to that time he considered them only as *parti-coloured* planes, or *surfaces diversified* with *variety of paint;* but even then he was no less surprised, expecting the Pictures would feel like the things they represented, and was amazed when he found those parts, which by their light and shadow appeared now round and uneven, felt only flat like the rest; and asked which was the lying sense, feeling or seeing?" (Smith's *Optics*, 1, 5, p. 43.) This story makes us acquainted with the progress of the human mind in these particulars. The distinctions of colour were natural, they seemed, from the first, familiar to the patient's comprehension, or at least were acknowledged as soon as perceived: but that an apparent variety of prominence and recess should result from adopting a variety of shade, was by no means an idea so soon to be acquired. His mind had not made the necessary observations on the appearance of objects in Nature to enable him to comprehend this fact; and hence it seemed to him quite easy to distinguish the object by different colours, but he required an explanation with respect to their distinction by means of light and shade. It is difficult for us in these days to recur even in imagination to the thoughts and ideas of an unenlightened mind; but we may learn much from this story. Thus, it is clear that the Painters in *chiaro-oscuro* showed greater skill than the Painters in various simple colours: it was indeed, perhaps, the most important discovery yet made by the artist; and we may add, that it was only the application of this same principle of the monochromatic style to a number of colours so combined together, that afterwards introduced the most perfect and beautiful of all the artificial processes with which the Art of design is acquainted. All the exquisite delight that is to be derived from variety of light, shade, and tint, flowed from the developement of this single principle of the monochromatic style.

School of the Ancients.

The next invention of which we find notice, regarded skill in Drawing, with respect to the attitude and posture of animate figures; and as former Painters had made all their figures stiff, alike, and upright in their lines, he was a great improver who first ventured to represent them with their heads looking upwards or downwards, or sideways, (the *catagrapha* of the ancient writers;) in short, who represented them in any way except that which was the most inefficient representation of the original, and yet the easiest to accomplish. The honour of this improvement is attributed to *Cimon of Cleone;* who also, with similar boldness of mind, ventured to make a fresh innovation in established practices, by marking out the muscles and veins of the human body, and the folds of garments.

Cimon of Cleone diversifies attitudes.

Phidias.

We next hear of *Phidias*, a person most celebrated indeed as a Sculptor, but who also exercised the sister Art of Painting: he flourished about the IVth century before the era of Christ. He is stated by Pliny to have painted a *Medusa's head* at Athens with wonderful skill. Of other artists of this date we may mention the name of *Mycon*, also an Athenian born, and, like Phidias, a Sculptor as well as Painter. He is celebrated for his preparation of a famous black pigment out of some part of the vine, (*trigynon*,) and seems to have turned much of his attention to the *matériel* of the Art; he is said also to have been the first person that made use of Attic ochre as a colouring substance in his Pictures.

Mycon.

Apollodorus

Apollodorus of Athens also possessed skill in both these lines of Art. It is recorded of him, that he was so fastidious as to destroy his finished works, and was in the practice of breaking them up, (whatsoever might have been the pains and cost expended,) if they did not correspond in the end to the conception which he had formed in his mind. The expression of Pliny with regard to him, that he was the first whose Painting fixed and absorbed the attention of the spectator, leads us to form a high idea of the improvements which he effected in this Art; and this idea is strengthened by the fact of his being noted as first showing the method of discriminating with delicacy the various gradation of shades in Painting. He seems also to have noticed that the colours of objects were to be preserved even in those parts which were darkened in shade, and hence he obtained among his countrymen the name of the Shade-Painter. It must be added, that this merit, asserted of Apollodorus by Plutarch, is attributed by Quinctilian to Parrhasius.

Parrhasius.

Parrhasius was a native of Ephesus who flourished about the same time, and a person who certainly greatly added to the advancement of the Art. He is universally praised for the attention which he paid to the symmetry of the human figure in Drawing, for his attempts to give an improved expression to the countenance, to form the curls of hair with grace, and carefully to finish the extremities of the hands and feet. But of all the great names among the Painters of antiquity, none, perhaps, are more celebrated than that of *Zeuxis*,

Zeuxis.

a native of Heraclea, one of those artists who came to Athens at the call of Pericles, and subsequently acquired great wealth by the practice of his profession. He it was that painted *The Venus* at Crotona, from a selection of the several beauties of all the fairest virgins of that city; and he it was that maintained the noted contest with Parrhasius, to which we have adverted elsewhere. Some of his designs, such as figures on vases and vessels of pottery, seem to have been collected and preserved with great care by the connoisseurs of ancient Rome.

Aristides. *Aristides of Thebes* is reported by Pliny to have been the first Painter who represented the various emotions of the mind, in the delineation of the human countenance. He depicted passion and sentiment with great success; but his works are said to have been harsh and unpleasant in their tone of colouring. We presume that he limited himself to the province of History; for the subjects ascribed to him are chiefly such as the following, *Bacchus and Ariadne, The Sacking of a Town*, and *A Battle between the Greeks and Persians.* We are furnished too, by the same author, with some clue to the pecuniary value at which the labours of an artist were commonly estimated; since in the last-named Picture, which contained one hundred figures, Aristides received ten minæ for each; the purchaser being Mnason the Tyrant of Elis. Attalus of Phrygia also purchased one of the Pictures of this artist at the price of one hundred talents; and when Greece fell under the arms of Rome, such was the rage of amateurship, that the price of six thousand sesterces at a public sale for a Picture was offered by the same King Attalus, and refused. Attalus, too, who seems to have been a great collector, went so far as to offer sixty talents for a Picture by Nicias of Athens; but here also unsuccessfully, for the Painter gave it to his Country.

Pamphilus. We may mention here, as relative to this part of our subject, the name of *Pamphilus of Macedon*, the master of Apelles, whose terms for instruction were so high, that those who complied with them must have entertained a vast reverence for Art. He received no less than a talent for ten years of tutorage, or, as the passage has sometimes been explained, a talent for each year as far as ten. It was by the influence of this same Pamphilus, that the law was first passed at Sicyon (where his School was held) which afterwards was adopted throughout Greece, That all boys born of free parents should be taught the Art of design; and to prove their admiration for it, the study was interdicted to slaves.

Apelles The story of *Apelles*, the Painter of Alexander the Great, is well known. He fell in love with Campaspe while painting her Portrait, and received her as a gift at the hand of that truly munificent monarch. It was Apelles too who once making a visit to a brother artist, to whom he was personally unknown, and finding that he was absent from home, left a sketch of a head in the hands of the domestic. Upon the return of Protogenes the sketch was shown to him, and he cried out, as it were intuitively, it must be Apelles himself, for no other mortal could have made this design. The most noted works of Apelles were an allegorical Picture of *Calumny, Alexander bearing a Thunderbolt, Venus rising out of the Sea, The Procession of Megabyzus, The Priest of Diana at Ephesus, Clytus arming for Battle, Menander King of Caria, Ancæus the Argonaut*, &c., besides which, during his visit to Rome, he painted a *Castor and Pollux*, a figure of *War* with her hands bound behind her, *Alexander the Great* in a triumphal chariot, a figure of *Victory*, &c. Sandrart makes mention of a specimen of ancient Painting, preserved in the Academy of St. Luke at Rome, which was certainly of Grecian origin, and generally considered as the work of Apelles. He has given an engraving of it in the *Academia Artis Pictoriæ*, lib. i. c. iv. p. 75. The improvement in the Art, for which Apelles is most celebrated, is the varnish with which he used to cover his Pictures, on which we shall presently have occasion to insert a remark by Sir J. Reynolds.

Protogenes of Rhodes will be readily recognised by the reader of History, as the Painter who succeeded in making the representation of foam at the mouth of a horse, by dashing his sponge in a lucky fit of passion upon his Painting. It was his Picture of *Temperance* which forced from the mouth of his rival Apelles that extravagant compliment, that it was a work worthy of being carried to Heaven by the Graces. Protogenes also painted the beautiful *Cydippe, A Satyr named Jalysus, Tlepolemus son of Hercules and Antiocke, Philiscus (the Tragedian) in meditation, King Antigonus, Athleta the mother of Aristotle the Philosopher*, and *A Sea-piece.* With his name we may close our account of Grecian Painters, as the Art seems to have declined greatly after his time, which, though he long survived that conqueror, we may call the Age of Alexander the Great.

As to the Romans, and the skill which they acquired in the Art of design, we know that no great taste for the Arts, either of Painting or Sculpture, was visible amongst them before the time of the capture of Corinth; and that almost every specimen which they possessed, even as late as the time of the Empire, was either imported from Greece, or the work of Greek artists settled at Rome. There was, indeed, one *Pacuvius of Brundusium*, a nephew of Ennius the Poet, who practised Painting; and we learn that one of the *Fabii*, who was living in the IIId century before our Christian era, made great proficiency in the Art, and painted with his own hand the walls of the Temple of the Goddess of Health and this work was preserved even in the days of Pliny. We gather, indeed, amidst the profusion of praise lavished on him by Cicero, that he was remarkable for the variety of his attainments, and in point of taste ranked far higher than most of his countrymen. An account is given us of a Picture, representing the battle in which he overcame the Carthaginians and Hiero King of Sicily, having been placed in the *Curia Hostilia*, by Marcus Valerius Messala, in U. C. 409. Lucius Hostilius Mancinus also, who first made an inroad into Carthage, exposed a Picture of that assault in the *Forum*, and used to seat himself there to explain it to the People. L. Scipio moreover put up in the Capitol a tablet to commemorate his conquest in Asia: we have no reason however to imagine that these monuments possessed any great merit as works of Art. We have the testimony of Virgil to show, that, even in his more civilized Age, these peaceful Arts were not held in much honour by the Roman People. Nevertheless, in a later day, the Art of drawing seems to have been taught to the youth of both sexes, and we find upon record the names of many females who attained a considerable degree of skill; Martia, the daughter of Varro, is mentioned in particular for her excellence in this line.

Protogenes. Roman School. Pacuvius. Fabius.

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Several Painters were resident at Rome during the reigns of Augustus and Tiberius. Of these, *Ludius* is celebrated for the taste and skill with which he decorated, with Painting in stucco, several apartments in the houses of wealthy individuals; and, as far as we can collect from Pliny, to him the Romans were chiefly indebted for the fanciful and grotesque taste with which these ornamental works were conceived. Many specimens of this description are to be seen at Pompeii, as also in the public Baths at Rome; and we know that from these Raffael, in after days, drew the ideas upon which his *arabesque* or *cinquicento* style was founded. Augustus seems to have been a considerable amateur; it was at his command that Apelles was employed in Painting at Rome. Some Pictures by Nicias also were placed in the Temples, and in the more conspicuous parts of the *Forum*, both by Augustus and Tiberius. Of the former we must presume, that he entered into the pursuit of the Art with all the enthusiasm of a private collector and *virtuoso;* for we are informed, that the curious sketch which Apelles left as a memento at the house of Protogenes, (as above related,) was purchased for the Imperial Palace. The Emperors Nero and Hadrian were not merely amateurs, but possessed considerable practical skill in Painting, and the latter in Sculpture also:

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Thus we have briefly noticed the gradual developement of the Art of Painting, from the days of its earliest invention to the period of the decline of that, as well as of every other Art, under the Roman Emperors. We have yet, however, to speak of the degree of excellence that it had at one time attained. With regard to the testimonies given by authors who were the contemporaries of some of the above-named artists, they can be considered only as speaking of their relative merit, that is, of each individual as compared with others of his day, or, at the most, with those who had preceded him; and of course their expressions furnish no criterion by which we can ascertain the degree of merit they might claim, when put in competition with the works of the modern School. But we have some specimens of ancient Art open to our inspection, it will be said, and we may form our judgment upon them; still, however, there is this difficulty, that we do not know the repute in which the artists who executed them were held in their day. If, for example, the Pictures in the Museum at Portici, taken from the excavations at Pompeii and Herculaneum, are to be regarded as specimens of the best powers of the ancient artists, (though it seems hardly fair to expect so much in the embellishments of a remote country town,) we can at once pronounce a decisive opinion on the subject. They are certainly very inferior to the productions of modern skill, with regard both to colour and general effect; but it must be admitted that they have, at least some of the best of them, a purity and elegance of design such as none but the most eminent and most illustrious of the modern School have ever attained. The very elegant figure commonly known under the name of *The Dancing Girl of Herculaneum*, is an example of the best taste. *The Nereid riding on a Sea Monster*, (*Antich. di Ercolano*, ii. 46,) the two sitting female figures in the Picture representing the *Sale of Cupids*, (ibid. 38,) *The visit of Juno and Minerva to Venus*, (ibid. 11,) *Ascanius and the Nine Nymphs*, (ibid. 3, tav. 13,) *The Europa* wrought in Mosaic, in the Barberini Palace, and the *Apollo giving a chaplet to a Poet*, taken from the Baths of Titus, are specimens which may be said to be of the very first merit in point of design; certainly nothing better than the three first-named has been produced in after times, unless by Raffael or Corregio. It is well known, that, at the time of their discovery, certain ancient frescoes were actually attributed by some virtuosi at Rome (strangers to their history) to those very masters. (See quotation in Turnbull, *On Ancient Painting*, p. 4.) Raphael Mengs, too, expressly says, that he thinks the design of the Ancients was much superior to that of the Moderns; "because among the ancient Paintings that I have seen, many are as well designed as the best of Raphael, notwithstanding they were done at Rome when the Grecian taste was a little vanished." R. Mengs, p. v. ch. iii. As another instance of beauty of design, we may mention the figure of the Girl playing on the harp in the *Nozze Aldobrandini*, as they are called, the most valuable of all the specimens of ancient Painting that have been yet discovered; it has been frequently made use of by N. Poussin in his compositions, as those who are acquainted with his works will allow. Not only the figure of the Harp-player, but many others in that piece, possess inimitable ease and grace of attitude. In short, we may declare that in these figures we recognise all that charm and power of the Art of design, which the excellence displayed by the Ancients in the sister Art of Sculpture might have led us to expect in their Paintings. To this, however, we must limit our encomiums upon the Ancient School.

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Defect of colouring

It is evident from the still remaining bright colours, scarlet, yellow, &c., which are seen on the walls of the apartments at Pompeii, that the colouring matter in general, as used by the Ancients, has lost little or nothing of its original freshness and vigour. Yet there is no science discoverable in their principles of colouring, as applied to their better Pictures; no richness of tint, no fulness of colour is attempted to be displayed; they have the harmony arising from universal meagreness and lowness of tone, but that is all. It is fair to add, perhaps, that real excellence in that line was scarcely attainable, until the invention of Oil Painting furnished newer and more promising methods of producing picturesque effect.

Oils unknown.

As to the secret of Oil Painting, we are sure they were not in possession of it, from the story related on the subject of the Picture of *Bacchus and Ariadne* by Aristides the Theban; for this Picture was carried to Rome and placed in the Temple of Ceres, and M. Junius the Prætor having ordered it to be cleaned, previous to the commencement of the *Ludi Apollinares*, all its beauty was destroyed by the application of water.

Opinion of Sir Joshua Reynolds on ancient colouring.

Sir Joshua Reynolds, in his comment on Dufresnoy's *Art of Painting*, makes the following remarks on the state of ancient Art, which are worthy of notice as coming from so great a master. "What disposes me to think higher of this colouring than any remains of ancient Painting will warrant, is the account which Pliny gives of the mode of operation used by Apelles; that over his finished Pictures he spread a transparent, liquid-like ink, of which the effect was to give brilliancy, and at the same time to lower the too great glare of the colour. '*Quod absolutâ operâ atramento illinebat ita tenui, ut id ipsum repercussu claritates colorum excitaret; et cum ratione magnâ, ne colorum claritas oculorum aciem offenderet.*' This passage, though it may possibly perplex the Critics, is a true and an artist-like description of the effect of glazing or scumbling; such as was practised by Titian and the rest of the Venetian Painters. This custom, or mode of operation, implies at least a true taste of that in which the excellence of colouring consists; which does not proceed from *fine* colours, but *true* colours; from breaking down to a deep-toned brightness those fine colours which would otherwise appear too raw. Perhaps the manner in which Corregio practised the art of glazing was still more like that of Apelles, which was only perceptible to those who looked close to the Picture, *ad manum intuenti demum appareret;* whereas in Titian, and still more in Bassano, and others his imitators, it was apparent on the slightest inspection. Artists who may not approve of glazing, must still acknowledge that this practice is not that of ignorance."

Examined.

Perhaps it is hardly fair to argue in favour of the general state of the Art, as Sir Joshua has done here, from a practice which Pliny states to have been a secret of Apelles alone, and known to no other artist; and there may, after all, be nothing more meant by the passage, than that he used a thin, transparent liquor, which he spread over the surface of his Paintings, in order to give them that depth of colour and general appearance of harmony, which such a process would naturally impart to a piece of dry colouring. Carlo Dati, indeed, in his Treatise *Della Pittura Antica*, translates the word *atramentum*, with a reference to this very passage of Pliny, simply as varnish; and it is obvious, that the use of a simple varnish would produce all that effect which Pliny describes; it would unite the clearness of the colours, as well as destroy their hardness. A varnish, indeed, which gave greater transparency than had ever been produced by the *encaustic* style of working.

Judgment of ancient Painters founded upon ancient criticism.

But we may assume, fairly, from the state of criticism exhibited in the writings of Philostratus, Pliny, or Quinctilian, or indeed any of the best informed ancient writers, that no great power was possessed by any of their Painters in the more artificial parts of the study. Unless we consider this passage of Pliny in the way in which Reynolds does, (which seems rather an overstrained interpretation,) there is nothing in any of their remarks which would lead us to suppose, that the delicacies and higher refinements of the Art were at that time known. Nothing can be more unartist-like than the general ideas expressed by these writers, and nothing less profound than their observations. They labour, like modern Commentators on the Classics, to display their own ideas rather than to illustrate the ideas of the author on whom they are employed, and present us with conceptions which could have originated only with themselves. The very course and line of their critical remarks is faulty; and as they were, no doubt, persons the best informed of their day, we must presume their ignorance was the natural result of the real imperfection of the state of the Art.

The works of Winkelmann, *On Ancient Painting*, and Junius, *De Picturâ Veterum*, are too well known to need mention here. In Turnbull, *On Ancient Painting*, much matter and several plates are given, illustrative of the imperfection of the Ancients in this department.

HISTORY OF MODERN ART.

Derived from Greece.

As in ancient times the Italians drew all their stores of Art from Greece, so we find even as late as the XIth and XIIth centuries, which are times comparatively modern, that all the best Painters came from that country. There are, indeed, some specimens of the works of native artists of that period still in existence, such as the Paintings in the Crypt of the Cathedral at Aquileia, at St. Primerano, at Fiesole, and in St. Brigio at Orvieto; but, still, the chief artists of any *repute* (for we cannot say *skill*) were natives of Greece, who were almost invariably employed not only in Painting, but in Sculpture and Architecture,—in short, in all that passes under the name of the *Arts of design*. Whether in these times there were not some examples of native talent in Italy, has been made a matter indeed of question; some perhaps there were; but the point in debate is of very little moment: greater admiration is due to the production of excellent works, than of those the merit of which lies only in their antiquity; and here the case is clear, the modern Italians owe none of that skill and power which distinguished the Age of the revival of the Art to any foreign quarter, but they drew it wholly from the resources of native genius, and from exertions both excited and rewarded by themselves. The Greek artists, it is true, were driven in abundance to Italy, as the Mahometan power began to encroach upon the countries wherein they had lived, and they brought with them the mechanism of their Art: but this is all that can be said; the first Painters whose names deserve a place in History were Italians born.

Cimabue and Giot

First we must mention the names of *Cimabue* and *Giotto*, both Tuscans, who probably studied under the Greek artists, but enlarged the principles of Art, and carried on their labours with a new and bolder aim than their masters; and having succeeded in forming a new style, travelled throughout many parts of Italy, and disseminated their knowledge in every direction, laying the foundation of that fame which the several Italian Schools in time acquired. Cimabue died in 1300, Giotto in 1336.

Cemete Pisa.

Towards the close of the XIIIth century the then powerful Republic of Pisa designed a splendid cemetery, in which were to be entombed the most illustrious of her citizens. It was named the *Campo Santo*. The superstitions of the day led them to import earth from the Holy Land for the reception of the dead, and a spacious cloister was raised around this sacred ground, in decorating the walls of which the most distinguished artists of Italy were employed. First *Giotto* and *Buffalmacco* commenced this work, then the two *Orgagni*, *Laurati*, *Simon Memmi*, *Antonio Veneziano*, and *Spinello;* and in the following century we find the works of *Bennozzo Gozzoli* added to the number. This last displayed great originality of mind; and the grace and expression of his figures, which were designed after a manner hitherto unknown, show him to have been the greatest regenerator of the modern Art of design. These Paintings, which were all executed in stucco, are yet remaining in the *Campo Santo*, though they may be better known to the world by the engravings of Lasinio, an artist of Pisa, which possess considerable interest, from the proof they give of the comparatively advanced state of Art in Italy, at a time when its inhabitants were

Chapel, as works of the pencil; and the *Pietà* in St. Peter's, and the Monument of Pope Julius in St. Pietro in Vincoli, in sculpture, sufficiently attest the powers of this wonderful man.

"The figures of M. Angelo are less Classical and studied in their form than those of Raffael, and though filled with equal, or perhaps sometimes superior force of expression, are yet more natural. Nevertheless, to call them purely natural, would be to give a poor idea of his excellence; it is seldom in Nature that we see personages who move as his figures seem to do: there is a species of internal intelligence exhibited by their external attitude, that few persons in common life appear to possess, and there is a degree of impressiveness in their air, that arrests and fearfully rivets the attention." (James's *Italian Schools*, p. 111.)

His pupils.

As to specimens of his style in Painting, there are few works in existence beyond those above mentioned which can be authenticated as genuine; but in the works of his best pupils and imitators, such as *Pellegrino Tibaldi*, *Sebastian del Piombo*, and *Daniel di Volterra*, we may trace the elements of what the Italians justly name *il grande gusto*. Michael Angelo is said to have furnished the design of the *Taking down the Body of our Saviour from the Cross*, which was painted by Daniel di Volterra for the Church of the Trinità di Monte at Rome; the engraving of which by Dorigny may be quoted as a specimen with which the Tramontanes are generally familiar; while we have, in the invaluable Picture by Sebastian del Piombo, in our National Gallery, a still more tangible illustration of the force of conception, and dignity of manner, inherited by the pupils of this great master.

Bartolomeo di S. Marco. Andrea del Sarto.

We are not, however, to suppose that he was the only Painter of eminence at that day at Florence; we have mentioned the name of Da Vinci, and we may also add those of two other Painters, scarcely inferior to him, *Fra. Bartolomeo di S. Marco*, and *Andrea Vannuchi*, called, from his father's profession of tailor, *Andrea del Sarto:* both of whom had Schools of Painting, and numerous followers, at Florence. Of the former, there are but few specimens in England which can give a fair idea of the noble simplicity of his composition. They are formed of few figures, seldom more than three, and mostly of a size larger than Nature.

Andrea del Sarto added another grace to the Florentine manner; his works partake, indeed, in every way, of what is called greatness in point of style, but it is combined with a certain suavity and gracefulness, which infinitely heightens the pleasure we receive in their contemplation. As far as he was an imitator of the manner of M. Angelo, he will be observed to have caught the feeling which that master showed in some of his earlier works in marble; that of the *Pietà*, for instance, in St. Peter's at Rome, or that more subdued conception of the beauty of form, which may be discovered in the Picture of the *Creation of Eve*, in the ceiling of the Sistine Chapel, and in some other of the compartments. His mind was naturally averse to that terrible sublimity of ideal Nature, with which, in later years, the mind of Michael Angelo seems to have been absorbed. The finest Painting of Andrea del Sarto is the *Madonna del Sacco*, as it is called, in the cloister of the Annunziato at Florence, an engraving of which is published by Volpato. We have a few Paintings of this master in England; but those who have seen only his early Pictures can form no conception of the greater talents which were developed by him in his works in fresco.

Florentine School.

XVIth century.

Towards the middle of the XVIth century there arose among the Florentine artists a style which was rather imitative of the more unessential peculiarities of Michael Angelo, than of his dignity and force; there is a certain heaviness, and empty ambitiousness of design, in the works of his scholars and imitators in general, but still we trace the remains of that noble spirit with which this great man inspired the Florentine artists. Of these we may make mention of *Giorgio Vasari*, the Historian of the Florentine School, who was much employed by the Pope at Rome, as well as by the House of Medici at Florence; *Lazzaro Vasari*, his brother; *Marcello Venusti*, who also settled at Rome; *Rossi*, or (as he was called from the name of his patron) *Rossi dei Salviati; Marco da Pino*, who lived chiefly at Sienna; *Jacopo Carucci*, (*alias Pontormo*,) of whom Michael Angelo is said to have prognosticated greater talents than he ever lived to display; *Rhidolfo Ghirlandaio*, descendant of the master of Michael Angelo; and *Pierino del Vaga*, a native Tuscan, who became the pupil of Raffael. We see the remains of Michael Angelo's style kept up, though in a still lower state of degradation, in the works of the pupils of these men, such as were *Angiolo Bronzino*, *Jacopo del Conte*, *Alessandro Allori*, *Zuccaro*, &c.

With regard to colouring, we cannot trace many symptoms of improvement until the days of *Cigoli* and *Pagani*, about the end of the XVIth century. Cigoli was a Poet as well as a Painter and Musician, and certainly succeeded in introducing a greater softness of manner, and higher brilliancy of colouring, than the Florentines had hitherto been accustomed to see. We may say, indeed, that this taste accorded better with the feelings of the Age in regard to these matters, at a time when the *bouquet*-like Paintings of Baroccio were generally rising into fashion throughout Italy. It was then that colouring, not expression, became the chief object of the Artist.

Carlo Dolce

Great skill with regard to the management of colour appears in the works of another master of that day, namely, *Carlo Dolce*, who attained high reputation, and had, like other great artists, his scholars and imitators. There was now no longer a demand for large Paintings as formerly in fresco, by means of which the Heroic style of Painting, if it may be so called, had been created and fostered from its birth; they were easel Pictures that were chiefly sought after by the wealthy. Yet *Franciscbini*, *Jacopo Empoli*, *Giovanni di S. Giovanni*, who belong to this period, are respectable names even among the Painters of large works, or *opere di machina*, as they are called.

XVIIth century.

Pietro d Cortona

Cipri

Acad Flore

After the middle of the XVIIth century a rich and harmonious style of colouring, and the more pleasing graces of Art, were brought more and more into fashion. *Pietro da Cortona*, who came to Florence from that city, which gives him his name, was engaged in the decoration of the Pitti Palace; and this public employment alone was enough to give currency to the style which he introduced at Florence. Of succeeding Florentines, none attained more celebrity than *Gio. Bat. Cipriani*, a name well known in England, both by his Pictures and the engravings made after them; elegance and beauty are their chief characteristics, and we see nothing of the original greatness of manner that once so proudly distinguished this School. The present Academy of Florence offers no remarkable distinctions of style and manner; but its professors are fully equal to those of Rome or Bologna, or Venice, and conceive their designs in that dramatic fashion which may be said now to be common in all parts of Europe. A very interesting Historical collection of Pictures, illustrating the different masters of Florence, and all the glories of their line, is preserved in their establishment in that city.

Roman School.

Raffael.

The Roman School comprises an extensive variety of styles, as all the Painters of eminence, from all parts of Italy, were attracted in succession by Papal patronage to the Eternal City. But the Roman manner, properly so called, is that of Raffael and his followers. With him, therefore, we commence its history.

Rafaello Sanzio da Urbino was born in the year 1483; he first studied Painting under his father, Sanzio, a tolerable artist, a specimen of whose style is still preserved, for the inspection of the curious, in the Brera at Milan. He next was placed under the tuition of an artist of great merit, Pietro Perugino, but he soon excelled his master: Pietro, indeed, only sought to give a true and faithful copy of Nature as she presented herself; while the ardent genius of his pupil aimed at a style drawn from the observation and selection of her excellencies only. Leaving Perugino, Raffael paid a visit to Florence, where the first objects that attracted his attention were the works of Massaccio, in the Church del Carmine; from these he began to acquire a little of that taste for the antique, which afterwards so much distinguished his character: and here it is, says Mengs, we find him "laying aside the style of broken and short folds of his late master." In a second visit to Florence, he seems to have been greatly taken with admiration of the style of Michael Angelo; and the new insight into the nature of his Art, which he derived from the view of that great master's works, taught him how necessary it was to abandon that mechanical manner which had distinguished all the artists of the last Age. He is supposed also to have gained great advantage as to his views in Painting, from the acquaintance which he then formed with the celebrated Fra. Bartolomeo di S. Marco.

"Being returned to Urbino he soon made known his progress, and discovered his new taste in a Painting of the *Deposition of our Lord*, painted in a Chapel. He was invited on that account by his uncle, Bramante, to go to Rome, where he was commissioned to paint in the new apartment, called *Di Borgia*, or *Della Segnatura*. He there began (according to different writers) by the four circles of the ceiling, in which he still preserved, as is very observable, much of the style of Father Bartholomew. This, however, pleased so much, that the Pontiff ordered the Paintings of the other Painters who had painted upon the walls to be cancelled, not being able to reign in competition with Raffael. He began, therefore, to paint one of the walls, representing the meeting of the Doctors of the Church, or, as it is generally called, the Painting of *Theology*, with the Trinity above, and with the Patriarchs intermixed with other Saints and Angels. The time in which he lived, and the little experience of his age, which could not be more than twenty-five years, made him renew the ideas of Perugino, from whence he drew the rays of light in gold relief, and there strung Angels and Cherubims, with other similar extravagancies. All the parts of that Painting are done with the highest attention, and one sees that he began with the right side, and terminated by the opposite. The parts which are towards the first side, one observes to be dry, painted therefore with diligence, and well impasted with colours; scarce any thing is retouched, and it is there one discovers the taste of Father Bartholomew. One sees that all the parts are taken from Nature; that is, copied from designs done from Nature; but the more the work advances, the more one beholds the successive progress of his good style, and one discovers also that, surmounting every timidity, he worked with more liberty." Raphael Mengs, *Remarks on the Style of Raphael.*

These remarks are valuable, as coming from one who was himself a very distinguished Painter, and one the greater part of whose early years had been consumed in constant and unremitting study of these works, so that no writer could be more competent to give an opinion upon them. The father of R. Mengs, indeed, is said to have obliged him to copy some of the Pictures by Raffael in the Vatican, no less than twenty several times. We must here observe, and the observation will be easily allowed by all who are familiar with Volpato's engravings of these subjects, that the *Borgo Incendiato* displays some little approximation to the style of composition and design before mentioned, as peculiar to the Florentine School, and the imitators of Michael Angelo: but in the rest of the noble works which adorn the *Stanze di Raffaello*, we trace the gradual formation and introduction of that new and peculiar style, which was from this day to become the pattern of the Roman School. Perhaps the *School of Athens*, in fresco, and the canvass Picture of the *Transfiguration*, may be quoted amongst the most illustrious and most perfect specimens: but in every figure that comes from the hand of Raffael, we mark that happy combination of grace and expression with dignity of form and manner, which has raised him to a reputation unequalled by any succeeding master. The *Cartoons* are familiar to all people in England, and afford us an admirable idea of the true Roman manner of design.

His pupils.

Raffael was assisted in his fresco Painting in the Vatican by a numerous band of scholars and followers; they executed, indeed, from his designs, the greater part of the works which boast his name. Raffael and his style now became the fashion of the day, though in some sort a rivalry existed between him and the still greater Michael Angelo; and sometimes a good deal of acrimony was displayed by their respective partisans. But all this tended to the general advancement of the Art; for upon the capture of Rome by the troops of the Emperor Charles V., the scholars of Michael Angelo, and those also of Raffael, who were far more numerous, flying thence were dispersed over all parts of Italy, and carried with them and disseminated the various principles of Art which they had imbibed from these two master-spirits of the Age. Thus *Pippi*, or *Giulio Romano*, as he is called, returned on this occasion to his native place, Mantua, where he set up a School of design, after the fashion of his master Raffael; *Benvenuto Tisi*, or *Il Garofalo*, did the same at Ferrara; *Gaudenzio Ferrari*, again, at Milan; *Pellegrino da Modena*, again, at that city; *Bagnacavallo* at Bologna; *Penni*, (*Il Fattore*, the steward of Raffael,) with *Polidoro Caravaggio* and *Perin del Vaga*, also taught the Raffaelesque style at Naples; and the last-named, who finally took up his residence at Genoa, communicating a new spirit to the artists of that wealthy place. There were others, again, of his pupils and followers, who continued their residence at Rome, chiefly employed in finishing many imperfect works of Raffael, who was carried off by death at the early age of thirty-seven; nor, indeed, did they ever feel the want of engagements, while those were yet living who had known their master's merit. Of this class were *Raffaello del Colle*, *Timotheo della Vite*, *Vincenzio da S. Gimignano*, *Vincenzio Pagani*, and *Giovanni da Udine;* the last-named being chiefly celebrated for his skill in designing the arabesque style of decoration, or *cinquicento*, as it has been called; a taste for which had been introduced by Raffael, being chiefly formed upon the antique remains discovered in the Baths of Titus.

Zuccaro.

As the taste of succeeding Popes varied one from the other, and as, in addition to this, there was an ever restless spirit of intrigue amongst those by whom the Popes were surrounded, it is not to be supposed that the followers of Raffael always maintained their ascendancy, or were constantly the subjects of exclusive patronage. First *Giulio Romano*, and then *Perino del Vaga*, had been promoted to the great object of professional ambition at that day, namely, the superintendence of the works carrying on at the Vatican. After these came *Daniel di Volterra*, the scholar of Michael Angelo, who introduced again the Florentine style; while, after a few years, the Raffaelesque manner was revived by the employment of *Frederico Zuccaro.* Though, we must confess, this last was but a very feeble and inefficient artist, yet he was a man of considerable influence in his time; and it is to his exertions that the Romans are mainly indebted for the establishment of the celebrated Academy of St. Luke, for the benefit of native artists.

XVIIth century.

The next work of importance which was undertaken by the Popes, namely, the ornamenting the interior of St. Peter's with designs executed in Mosaic, was intrusted chiefly to Florentine artists, who thus became once again in fashion. There were also Schools of Painting, of considerable reputation at the beginning of the XVIIth century, established at Rome by *Muziano*, *Raffaellino da Regio*, and the *Cavalier d'Arpino;* and these too, for a while, exerted an influence on the public taste, and claimed a share of popular admiration.

Baroccio.

But the chief and most splendid novelty which appeared after the day of Raffael, was the brilliant method of colouring adopted by *Baroccio*, who embellished the Roman manner by the introduction of a vivid, one might almost say a spotted, style, united with something of that graceful mode of design which had first been seen in the works of Corregio. But this ingenious and deserving artist was driven away from Rome by the envy and jealousy of his contemporaries; he died in the year 1612, as is generally supposed, by poison.

Caravaggio.

His followers.

M. A. Caravaggio also obtained great success at Rome by the invention of a new style: his peculiarity was the use of a dark background to his figures, which gave them a strong and forcible relief. Great was the admiration it excited; and hence he had many followers. A Flemish artist, by name *Honthorst*, or *Gherardo delle Notte*, and also *MM. Valentino*, and *S. Vouet*, both natives of France, painted after the fashion of Caravaggio with great success at Rome.

The Caracci.

Guido.

Domenichino.

But that which most occupied the public attention at the beginning of the XVIIth century, was the novel manner of design adopted by the family of the *Caracci*, at Bologna. They formed themselves after the purest principles of Nature, in opposition, as it were, to the Classic styles of Raffael and Michael Angelo; and as they gave great force and expression to their Pictures, they succeeded in rivalling the most admired productions of the previous century. This new manner was first shown to the Roman Public in the Paintings executed for the Cardinal Farnese, in his Palace, which is to this day one of the greatest boasts of the city. Being once known and approved in the Papal Metropolis, the taste for their style soon became very general throughout Italy; and the magnificent productions of the scholars of the Caracci, who soon followed their master to Rome, such as the *Aurora* of *Guido*, and the *St. Jerome* of *Domenichino*, sufficiently attest the nature of their success, and the merit of their inventive powers.

Lanfranc of Parma, the Painter of the Cupola of S. Andrea della Valle, and *Guercino*, the Painter of the *Aurora* at the Ludovisi Palace, illustrated this period, and contributed many specimens of their skill to adorn the Palaces of the wealthy Nobles of Rome. Indeed, at no time were there more men of genius and talent attracted to that city, than during this and the succeeding Age. By the time we have arrived at the middle of the XVIIth century, we find the names of *Salvator Rosa*, from Naples; *Claude Lorrain*, and *Elsheimer*, from Germany; *Antoni Tempestá*, from Florence; the two *Poussins*, from France; *Velasquez*, from Spain; and *Vandyke*, from the Low Countries; all of whom left behind them numerous works, which are numbered to this day amongst the rarest treasures of Rome.

Pietro da Cortona.

Ciro Fer

Pietro Berrettini da Cortona, a Tuscan by birth, was the next person who may be said to have had an influence on the taste of the day. He came into favour at the Papal Court, chiefly in consequence of his interest with the sculptor Bernini; an able artist in his way, but who may be said to have introduced much the same sort of pleasing diffusiveness of style into the Art of Sculpture, as his *protegè* displayed upon the canvass. P. Cortona was in favour under the reigns of Urban VIII. and Innocent X., and has left a rich specimen of his taste in design, in the celebrated painted ceiling of the Barberini Palace at Rome. He died in 1670; and we may mention as one of his best followers the name of *Ciro Ferri*.

Andrea Sacchi.

Carlo Maratta.

Contemporary with him, and superior in merit, though less the favourite of fame and fashion, was *Andrea Sacchi*, a man of undoubted genius, and who would, if duly patronised, have shed more honour and lustre on the declining days of the Roman School than any other Painter of this period. We must look, however, to still more degenerate days, when his pupil, *Carlo Maratta*, as was the case a short time afterwards, became the leader of the public taste, and the idol of the profession. The style of this master is singularly heavy and dull; and yet towards the end of the XVIIth century, at which we are now to consider ourselves as having arrived, he was regarded as the best artist in Italy; many of his Pictures have been engraved, and they need no comment, they speak for themselves.

Raffaell Mengs.

Raffaelle Mengs succeeded; a native, it is said, of Saxony, but who was naturalized by long residence at Rome, and still more so, by a long course of Roman study. He possessed unwearied diligence, and at least so far deserved success, though he had no kind of pretension to that fire of genius and originality, which had formerly been supposed necessarily to belong to one who was the leading artist of Rome. In his Pictures, however, he exhibited great delicacy and elegance of colour; nor was his design void of grace; but beauty rather than greatness of manner was his aim, and in this he was successful. The traveller in Italy will remember his Paintings in the Villa Albani. *Pompeio Battoni* was an artist of the same stamp, though much his inferior; and the modern School of the present day is generally formed after the same fashion. *Camuccini* is perhaps the most eminent amongst its disciples.

Venetian School.

Venetian School.

Under the title of the Venetian School are generally comprehended all those artists who flourished in the territories of the Venetian Republic on *terra firma*, as well as those of Venice itself. If, therefore, we were to enter into every branch of Historical research to which we might be led in this wide field, we should wander amidst early details of various incipients in Art, among numerous petty States, which would be viewed with little or no interest. We may observe, therefore, that as the Venetian School dates all its splendour and fame, and most of its distinguishing characteristics, from the days of the great Titian, the contemporary of Raffael and Michael Angelo, the founders of the Schools of Rome and Florence, its real History commences with him. Lest we seem to pass over this period too lightly, we will just remark, that a taste for Art had even before his day displayed itself in these parts; that at Vicenza and Verona we find the names of *Liberale, Il Marescalco, Merone, Montagna;* at Bassano, some of the earlier artists of the family of *Da Ponte;* while at Padua a famous School was formed by *Squarcione*, where no less a person than *Andrea Mantegna* received his education, who was largely and honourably employed, both by Pope Innocent VIII. at Rome, and by the reigning family at Mantua. In Venice itself, too, even at this early period, we find *Giovanni* and *Gentile Bellini*, and *Vittore Carpaccio*, exhibiting great diligence in the prosecution of the Art, and exciting the public attention by their efforts. The Government indeed thought it of such consequence to encourage the School, that it purchased for it the secret of the newly discovered Art of Painting in oil, or, to speak more correctly, the improved method of Painting in oil, which had been brought from Flanders by *Antonello di Messina;* and a specimen of his painting made for this purpose, is now preserved in one of the public buildings at Venice. Of the style of design adopted in this day, we have before spoken, and have only to add, that it is remarkable that even at this early period the attention of the Painters was directed more especially to the improvement of their system of colouring, than to the other points of excellence, and in that respect they were already advanced far beyond any of the other Italian professors. It would be unjust, however, to pass in silence the merits of so great an artist as *Giorgione*, the pupil of *Bellini*, who in the course of a short life attained to such a degree of perfection in colouring, as excites the highest admiration even at the present day. He is said to have been the first artist who introduced the fashion of decorating the exterior walls of houses with painted figures; and some specimens, traditionally assigned to him, were till within these few years to be seen at Venice: one or two of them were engraven by *Zanotti*. As the easel Pictures of Giorgione were very few, it is rarely that we meet with his works in the cabinet of the amateur. He died at the age of thirty-two, just when *Titian* was advancing to the zenith of his reputation. The length of this last-named Painter's life, for he lived ninety-nine years, greatly contributed to his advancement of the Art at this early period. Titian died A. D. 1576.

Titian.

"Titian displayed much of the *beau ideal* even in his colouring, and though his design possesses much of dignity and expression, yet it was in this he chiefly excelled, and to the perfection of which, rather than of any other branch of practice, that his attention was chiefly directed. He knew perfectly well, from having made it the object of his study, the characters and degrees of each colour, as also the proper place in which to apply them. The science of placing a red cloth in preference to a blue one, is not so easy as is imagined; and this is what Titian understood in the highest perfection. He likewise very well knew the harmony of colours, which is in part ideal, and which one sees not in Nature, if it be not first comprehended in the Imagination." Raphael Mengs, p. iv. ch. v.

The Portraits painted by Titian (or *Vecelli*) are now regarded as the most masterly examples of skill in that department of the Art. His Historical compositions are some of them of a rank scarcely inferior; and such was his universality of talent, that even when he turned his pencil to Landscape Painting he succeeded in that also. As a strong proof of the esteem in which he was held at Venice, even during his lifetime, we may relate that he was by a public decree of the State exempted from taxation; and this honourable fact affords us evidence enough of the generous ardour with which the Arts were at this day encouraged. That a Prince should become a patron, is no more than natural from the feelings of the individual; but that a Republic should publicly reward talent of this description, is attributable only to motives of the most enlightened and exalted liberality. Titian had several brothers who also followed the profession, and whose names, and consequently their works, are sometimes improperly confounded with his. The scholars of Titian and imitators are, however, of more consequence to our inquiry. Of these *Jac. Robusti*, better known under the nickname of *Tintoretto*, (the dyer,) stands first in point of eminence. The object at which he aimed was one that required no ordinary boldness of mind to attempt; it was nothing less than to unite the noble skill of design of Michael Angelo with the rich and graceful colouring of his master Titian, and he has to a certain extent at least succeeded in his aim. It is indeed chiefly by the general air of greatness of style in his compositions, that his Pictures may be easily distinguished from those of other masters of the Venetian School. But let it be observed, that the easel Pictures by this master, which usually find a place in every collection throughout Europe, will serve to give a very feeble idea of the powers of his mind; it is at Venice alone that the connoisseur is enabled to form a due estimate of the merits of Tintoretto. He, too, had his scholars and followers, amongst whom may be reckoned not only many Venetians but also *Rothenamer* of Munich, *Martin di Vos* of Antwerp, and several other north countrymen.

His Pupils.

Tintoretto.

Next in point of reputation stands *P. Cagliari*, Paolo Veronese.

or *Paul Veronese* as he is more usually called, for his residence was at Verona. His style is more brilliant and diversified in point of colouring than even that of Titian; but he possesses none of the greatness of design belonging both to him or to Tintoretto. The same air of ease and profusion which distinguish his system of colouring, are seen to pervade the character of his design; all that comes from his pencil is rich, harmonious, and free. He may be easily discernible amidst all the other leading masters of this School, by the intrusion into his composition of a black-faced Moor, or a Venetian nobleman or lady, or a dog; all of which, though introduced in direct contradiction to common ideas of propriety and truth, yet in his hands are so admirably managed, as never to appear unpleasing or unnatural. The *Farinati, Brusasorci* and their School, the family of *Del Moro*, were amongst his best scholars. We may add the name too of *Batista Zelotti,* who perhaps approached the nearest to his manner of any, and whose Pictures are often confounded with his.

Bassano.

Palma.

Jacomo da Ponte, or *J. Bassano* as he is more commonly called, together with his brothers and his sons, formed a large School at the city of Bassano. They all painted much in the same manner, that is, with dark backgrounds and sharp, cutting lights; but it must be allowed, that from this practice, combined with the Venetian mode of colouring, resulted the most harmonious, rich, and mellow effects that can be produced on canvass. Bassano, in fact, seized upon a species of effect which is sometimes to be remarked as produced in this fashion in one or two Pictures of Titian; and building a manner upon these, perhaps, almost accidental examples of his master, appropriated and made it his own. Other illustrious names besides these are to be found among the scholars and imitators of the great Titian, such as *Paris Bordone, Il Pordenone, (A. Licinio,) Bonifazio, Andr. Schiavone, Aless. Bonvicino,* (or *Moretto di Brescia,*) who also had his School at that city. In the following century an inferior race sprang up; still, followers of Titian, still, admirable colourists, but betraying both in the principles on which their system of colour is conducted, as well as in their general design and conception, that littleness of mind which always belongs to the imitative class. Of these, *Palma the younger* may be mentioned as having attained the highest reputation. We might add the names also of some other Painters not unknown to fame, and who owed their success, in great measure, to their happy method of combining with the peculiarities of this School some of the novelties of style, which we have elsewhere said became fashionable in the course of the XVIIth century throughout Italy. Such were *Cantarini* and *Tinelli* at Venice; *Dario Varotari* of Verona; and *Alessandro Varotari,* or *Il Paduannino,* a name which he attained from his School being removed to Padua, where it became one of the most celebrated of the day; in saying, indeed, that *Pietro Liberi* was one of its ornaments, its excellence is sufficiently proved.

XVIIIth century.

Canaletti.

In the XVIIIth century we find few names of any great account among the Venetian Painters; yet those who attempted, after their fashion, to redeem the lost fame of the School, chiefly showed their talent in the same line as their predecessors, namely, in the art of colouring. *G. B. Piazzetta* and his scholar *Tiepolo*, as well as *Sebastiano Ricci* painted, it must be admitted, though not in the great style, yet with much spirit and beauty. And no individual, certainly, ever contributed to make the scenes of his native city more familiar to the eyes of the rest of the world, than the last great Painter of Venice, *Antonio Canal,* (or *Canaletti.*) His richness of tone and colour in his best Pictures stands unrivalled in its way: nor does he deserve less praise for the decision and firmness of his touch. There are two of his followers, *Marieschi* and *Guardi*, whose Pictures are sometimes sold under his name; but those of the former may easily be known, by their timidity of touch, and heaviness of colour; those of the latter, by his frequent use of hard lines, to give precision to his buildings and figures, resembling the marks in pen and ink sketches.

School of Bologna.

Francia.

Tibaldi.

The works of *Francesco Francia,* a contemporary of Raffael, will always be the subject of great admiration with the amateur who pays a visit to the city of Bologna, and not less so because he will seldom have heard the name before; nor will he less admire, perhaps, those of *Ramenghi,* (or *Bagnacavallo,*) a pupil of Raffael, and the frescoes of *Pellegrini Tibaldi.* This last was the pupil of Michael Angelo, and one who, had he persevered in the Art of Painting, might have risen, if we may guess by what he has left behind him, to the highest possible eminence. He certainly possessed a great part of the sublime conception of his master, while at the same time he had the taste and sense to avoid his extravagancies: he is usually called *Il Michael Angelo riformato.* He was also an Architect, and designed the Cathedral of Milan after a semi-gothic fashion.

The Caracci.

Domenichino.

Guido.

Albani.

Lanfranc.

Primaticcio and *Nicolo del Abate,* who afterwards left their country to prosecute their fortunes under the French Court, also belong to the early days of the School of Bologna. But this city owes its chief fame, as is well known, to the family of the *Caracci,* who began in the XVIIth century to attract universal attention, and finally gave the law to the rest of the Italian Painters. The style they introduced was formed from the study of Nature; and in this respect is opposed to the more learned and Classical manner of Raffael and M. Angelo, which hitherto had been in the highest repute. It was not, however, pure Nature which they cultivated, but rather Nature assisted by all the picturesque science which had been brought to light by the sagacity of the preceding Ages: for the example of each of the more eminent of their predecessors was recommended in the instructions which the Caracci gave to their pupils. *Ludovico Caracci* (whose Picture of his family is now to be seen in the Library at Christ Church, Oxford) was the first to commence this new era of the Art; but he was ably supported by his cousins *Agostino* and *Annibale.* It was from their benches came the most distinguished Painters of this Age, and to the truth of the principles which they inculcated we owe some of the most brilliant specimens of Art. *Domenichino,* the Painter of the famous *Communion of St. Jerome; Guido,* the Painter of the *Aurora* in the Rospigliosi Palace at Rome; *Albani,* the graceful Painter of women and children; *Lanfranc,* a Painter of frescoes and *opere di machina,* as they are appropriately termed in Italy; all these were the scholars of the Caracci, and from the wonderful talent they exhibited, were soon called to share the patronage of the Papal Court at Rome. Once established there, they too had severally their Schools and their scholars, and contributed in their

inting.

turn to form a fresh supply of vigorous artists, and carried down to a third generation the principles of the School of the Caracci.

rcino.

Guercino was a native of Cento near Bologna, but it is not known that he ever studied under the Caracci, though his manner approaches so near to theirs, that (as he was their contemporary) it has often been so suspected. His particularity of style chiefly lies in an happy method of scattering and interchanging his light, and still preserving his harmony. In his design there is a grace that approaches sometimes nearly to that of Guido; but he is generally very faulty in the drawing of the hands and feet, and this is a mark whereby his Pictures may be known. Both these masters for a certain period of their lives adopted the fashionable, and then novel manner of Caravaggio, by introducing a black background in order to force out their figures.

Some of the School of the Caracci remained behind at Bologna, and attained a very high reputation, which will be seen to be amply merited by their works remaining at this day in that city. Among these may be named *Tiarini*, *L. Spada*, *Cavedone*, and *Il Gobbo de'. Caracci*, an *élève* of that family, a Painter of fruits, &c.

Carlo Cignani may fairly be said to have maintained, even so late as the XVIIIth century, something of the original character of the design of the Caracci, or rather he followed their style, such as it became in the hands of Guido, and met with well deserved honours as a Painter. *Gioseffo del Sole* also, and *Passignani*, had Schools under them of much reputation. In the next generation, *Francheschini* and *Crespi*, the scholars of Cignani, were the most in repute. And even at this day, while we notice a very curious and valuable series of Bolognese Paintings in the Academy at Bologna, we must not forget, that there are also many living professors of the Art of considerable talent, still zealously pursuing the great line of Historical Painting.

Other Italian Schools.

In the valuable history of the Italian Schools by the Abbé Lanzi, the account of no less than fourteen is historically detailed: they are not, however, or at least ought not to be, reckoned Schools in the same sense in which the preceding four are so named. He gives us, in fact, no more than a narrative of the efforts made in the prosecution of this Art by the other chief cities of Italy, but in which no general style and manner was ever promulgated, nor did they ever give the law in Art to the rest of their countrymen. Of these the History of *Parma* should stand first, in regard to the merit and reputation of its Painters. The style of *Corregio*, (or *Allegri*,) the great boast of this city, was, if ever such an assertion may be made of any one, purely his own. His example, however, exerted but little influence on others, and his style was soon supplanted by the introduction of foreign novelties.

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Other Italian Schools.

Corregio's style is the favourite theme of Raphael Mengs, nor can we do better here, perhaps, than quote the following passage from his writings. "In Corregio one finds a spirit mild and soft, which gave him an aversion to all that which is too powerful and expressive, and made him choose only such parts as were pleasing and tender. He began to study almost only the imitation of Nature; and since he possessed more a graceful and pleasing genius than a perfect one, he found out the way at the beginning, by means of uniformity, and depriving his drawing of every angular and acute part. He drew his outlines in a serpentine manner. In general his design was not too just, but great and pleasing." p. 11. ch. vi. Mengs adds a remark too which is not void of a certain degree of sagacity, namely, that he should not advise any artists to study Corregio, unless they felt they had a sensibility like his; a remark that may be extended to many other cases of imitation. "When a Painter," says he, "in the meantime that he invents can transform himself, as one may say, into that which he would wish to imitate, he will imitate well; if he cannot, it will always be better to follow that which he feels of himself," i. p. 67.

The chief Paintings by Corregio are the frescoes which adorn the Cupola of the Cathedral at Parma, and that of the Church of San Giovanni, at the same place; there are, besides, some other splendid Paintings in fresco by this master to be seen at Parma; as to his easel Pictures, though they are to be found scattered through all the great collections in Europe, no one being held complete without such a specimen, yet we may particularize the Royal Gallery at Dresden, as being the richest in this respect, and possessing his best productions. The two cabinet pieces placed in our British National Gallery are beautiful in themselves, but too small to give any just idea either of the greatness of conception which distinguished Corregio, or yet of the graceful beauty and peculiar fleshiness of his forms. Of this master perhaps may be said with justice, that he combined in himself more of the qualities requisite to form the perfect Painter than any other man upon record.

Parmegiano.

Parmegiano, (or *Parmegianino*, as he is generally called in Italy,) though inferior to Corregio, was in some respects an inheritor of his talent, but he rather caricatured the spirit of gracefulness and elegance which he studiously sought to imitate.

Lanfranc.

The name of *Lanfranc* deserves a place here; for, though afterwards a follower of the Caracci of Bologna, his style was first formed at his native place Parma, and chiefly from the imitation of the works of Corregio. His greatest work was the Painting in the Cupola of St. Andrea della Valle at Rome.

School of Sienna. Sodoma.

The great boast of *Sienna* is *Giantonio Razzi*, commonly known by the name of *Sodoma*: his easel Pictures are few in number, and therefore his name is not so familiar to the world as it deserves to be; whereever they are to be seen, they will always be acknowledged as the works of a first-rate master. He was one of those artists who were called to Rome, and employed by the Pope in adorning the chambers of the Vatican Palace, and whose Paintings were effaced by order of Julius II., when the commission to paint the *Stanze*, as they are called, was transferred, on account of his extraordinary merit, to Raffael. There is a fresco Picture by Sodoma, in the cloisters of the St. Caterina at Sienna, which marks him as being, if inferior, nevertheless inferior to Raffael alone. *St. Catherine* fainting in the arms of her attendants is one of the most successful pieces in point of expression, simplicity, truth, and delicacy of feeling, that ever was produced.

The designs of his scholar *Beccafumi*, executed in *pietra commessa* (or marble inlaid) on the pavement of the Cathedral at Sienna, are also conceived in a grand and classical style.

Baldasar Peruzzi, Architect and Painter, as well as

Marco da Pino, were also of Sienna; and in more modern times we have the names of *Casolani*, *Salimbeni*, and *Vanni*. A series of the Paintings of the native artists is preserved in the Academy at Sienna.

School of Milan. Leonardo da Vinci. *Milan* first became celebrated for her school of Art in the days of *Leonardo da Vinci*, who, as was before observed, was brought hither from Florence by the order and under the patronage of the Government, and was employed here as Architect, Civil Engineer, and Painter. The famous Picture of the *Last Supper*, in the Refectory of S. M. delle Grazie, is one of the most celebrated compositions in the world; and although but faint traces are left of the original work, it is happily preserved to us in the faithful engravings of Morghen and others, and also in the copies made by the Milanese scholars of this great man: of him, however, we have already spoken under the head of the Florentine School.

Luino. *Bernardino Luino*, if not his scholar, is at least the most successful and the best of his imitators, possessing indeed so much of original talent himself, as scarce to deserve the name of imitator, if applied to the servile fashion which it commonly describes. Many frescoes from this master are placed in the Picture Gallery of the Brera at Milan; but there are some still finer specimens of his talent to be seen in the Hotel of the Croce di Malta, and in the Church belonging to the village of Sarono.

Ferrari. *Gaudenzio Ferrari*, the pupil of Raffael at Rome, was also a Milanese, and formed for himself a School of his own, upon his return to his native city. Of later names which do credit to Milan, we may mention the family of the *Procaccini*, who were three in number, *Camillo*, *Giulio Cesare*, and *Ercole*: and in the beginning of the present century *Appiani* was living at Milan, a native artist who has given the best specimen of fresco Painting in the last century, in the Church of S. M. in Celso.

School of Naples. Among the *Neapolitans* we find but little originality: the respective styles of Michael Angelo and of Raffael were taught by their scholars, who had settled in this city, and to imitate them well was all that in their days was required. Spagnuoletto. *Spagnuoletto* had talent, and he seems, from the best accounts we have met with, to have been born in the Neapolitan territory. There is, indeed, a singularity and boldness in his style which stamp him as no ordinary genius. But we cannot consider him as in any shape the inventor of a style: that which he possessed was chiefly built upon the principles of M. A. Caravaggio; but his lights had less of breadth and of glaringness of effect in them, than those of that master. Contemporary with him was the *Cavalier Calabrese*, a no mean Historical Painter in his day.

Salvator Rosa. *Salvator Rosa* was the pupil of *Aniello Falcone*, who migrated to France, and settled there; he too left his Country as soon as he had attained any degree of eminence in the Art, in order to seek his fortune at Rome: and he must be pronounced by all to be truly original. He was a Poet, a Musician, and Satirist, the life and spirit of the Carnival in the year in which he arrived at Rome, and one of the best Landscape Painters of the day, even while Claude and Poussin were yet living. A certain contradiction of humour, however, for it is difficult to give it any other name, was the cause of his being perpetually involved in troubles: and if it promoted a disposition in him to seek out and produce of himself what was new and original, because it was in opposition to the taste of others, it certainly, so far, was advantageous to the Art. But we must say this only of his efforts in Landscape Painting, for this same pride of mind led him quite astray when he attempted the Historical line; and his life was unhappy, because he was perpetually struggling against the public voice, which condemned, and justly too, all his Pictures of that description.

Luca Giordano. *Luca Giordano* flourished at Naples towards the middle of the XVIIth century; he was one of the best imitators of the style of other Painters in general that has ever been known. Pictures, as if from the hand of Albert Durer, Titian, Raffael, P. Veronese, P. Cortona, all were produced with equal facility by his free and happy pencil. As for his own style, there is an azure colour which seems to form the standard of his composition, and with which the most brilliant and fascinating combinations are sometimes most skilfully formed; in his figures he chiefly reminds us of the the stolen beauties of the above mentioned Painters. His Pictures are very common in the collections of amateurs, and those of his scholars, who are numerous, are often sold under his name. *Paolo di Matteis* is reckoned the best of them.

School of Mantua. Mantegna. The first Painter whom *Mantua* can boast is *Andrea Mantegna*, who is generally classed under the head of the Venetian School, being a Paduan by birth; he is one of those great men who may be classed among the fathers of modern Art: he died in 1506; some very fine specimens of his manner are preserved in the Palace at Hampton Court.

Giulio Romano. Soon after his day appeared in this city one of the ablest of the pupils of Raffael, who was a native of Mantua, namely, (*Pippi*) *Giulio Romano*,—"that rare Italian master, who, had he himself Eternity, and could put breath into his work, would beguile Nature of her custom; so perfectly is he her ape." (*Winter's Tale*, act v.) Shakspeare was mistaken in one point, as Giulio Romano never practised Sculpture, of which he is speaking in this passage. Nor is the remark otherwise just, for it was not the exact imitation of Nature in which he excelled; his merit is this, that his conceptions are filled with Poetical imagery, and all the beauties of ideal scenery. The *Battle of the Giants*, a fresco Painting in the Palazzo del Tè at Mantua, is one of the best examples of his ability; all the lesser Paintings of varied sorts in the several compartments of the walls and ceilings, and even the arabesque ornaments, are also designed by him. He was, moreover, the architect who planned and executed the structure itself, which, in spite of a few whimsical irregularities of design, has infinite merit: there are many effects of picturesque grandeur in building, which impose upon the Imagination far beyond any of those Classical delicacies which the rule and compass can effect almost of themselves. His own house, or Palace it might be called, is here still pointed out to the attention of the traveller; for he spent the latter part of his life in his native place. *Ippolito* and *Lorenzo Costa* were among the best scholars that he left behind him. *Domenico Feti*, from Rome, lived for some time at Mantua under the patronage of the Court.

School of Modena. Pellegrini. *Modena* boasts of having contributed one distinguished artist to the School of Raffael, namely, *Munari*, better known by the name of *Pellegrino da Modena*; for his best works we must go to Rome.

Orsi. *Lelio Orsi* was also a native of this place; but he too remained here but a short time, having been banished by the Court, and afterwards settling in Piedmont, in which Country many very fine compositions by him are to be met with: there is no foundation, however, for the story commonly related, namely, that he was a pupil of Michael Angelo.

chedone.

Bartolomeo Schedone, a not unsuccessful imitator of Corregio's style, comes under the head of the School of Modena.

chool of remona.

Cremona has the merit of having sent forth some Painters of considerable talent in the earlier days of Art, such as the two *Boccacini*, father and son, and *Bernardino Gatti*, or *Il Sojaro*.

he Campi

But its chief fame is owing to the School formed here, in the middle of the XVIth century, by the family of the *Campi*, who were four in number, *Giulio*, *Antonio*, *Vincenzio*, and *Bernardino*. Their style was partly composed from that of Giulio Romano, but its strange features were softened down by the addition of the Corregiesque gracefulness of attitude and beauty of colouring. They were very successful in their day, and their Pictures, if not common elsewhere, are often to be seen in Lombardy. They too had a follower in *Gio. Bat. Trotti*, or *Malosso*.

chool of errara.

We find one of the pupils of Raffael settled at *Ferrara*, who retired from Rome with considerable reputation, and gave up his latter years to his native city.

arofolo.

His name is *Benvenuto Tisi*, (or *Il Garofolo*, as he is called, because he used to paint a clove or violet upon his works, as his private and peculiar mark.) In him may be traced much of the elegance of the School from which he issued; and his colouring savours of those principles which guided his master in his latter and better days. *Girolamo da Carpi* was the scholar of Garofolo at Ferrara.

lippi.

The style of Michael Angelo too was cultivated here by *Camillo Filippi*, who has left a specimen of his talents in a Picture of the *Last Judgment*, in the Choir of the Metropolitan Church.

Scarsellino, with his pupil, *Camillo Ricci*, may be classed among the imitators of P. Veronese, and *Gian. Mazzuoli*, (or *Bastaruolo*,) together with his pupil, *Carlo Bonone*, of Titian, and with their names we must close the account of Art as cultivated at Ferrara.

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Perino del Vaga, another of the School of Raffael, introduced the manner of that master at *Genoa*, soon after the general dispersion of the artists from Rome upon the sacking of that city by the troops of Charles V. By his instructions were formed two brothers, *Lazzaro* and *Pantaleo Calvi*, who were very respectable Painters: and it is to be presumed that the other Genoese belonging to this era, such as the two *Semini* and *Luca Cambiaso*, (the same who went to Spain,) drew the principles of their style from the same source, though they were not actually his scholars. A certain Noble, *G. B. Paggi*, (the first instance at Genoa of a Patrician so devoting himself,) continued the profession towards the end of the XVIth century, and became one of its most distinguished ornaments. But far from limiting their patronage to their countrymen alone, the wealthy Genoese sought in an after Age the assistance of those who bore a high reputation abroad, inviting and encouraging the residence among them of some of the most celebrated foreign artists. *Rubens*, *Vankyke*, *Simon Vouet*, and many others, in this way, remained a long time engaged upon Painting in this city, and have left behind them many splendid memorials of their skill and ability. Native talent, however, was by this means considerably depressed; and we find the latter annals of this School, as it may be called, filled with few names of any note or distinction. The two *Carloni*, and *Bernardino Strozzi*, (*Il Prete Genovese*,) were respectable Painters, as also were, in still more modern days, *Il Grechetto*, or *Giovanni Benedetto Castiglione*, and his two sons: these last, however, chiefly excelled in painting animals.

Of Piedmont and Savoy.

In *Piedmont* and *Savoy* also we find that foreigners, (for so they call the natives of other States of Italy,) chiefly engrossed the public patronage, and there are few instances of native artists who rose to eminence. *Giorgio Soleri*, of Alexandria, however, in the XVIth century, appears to have painted several altar-pieces for Churches, and to have made some Historical pieces which are now remaining. We may quote also the name of *Gul. Caccia*, (or *Moncalvo*,) of Monferrato, with those of his two daughters, *Francesca* and *Orsola*. *Antonio Molinari*, (or *Caraccino*, as he is sometimes called from his imitations of the Caracci,) was a native of Savoy, but he expatriated himself, and passed the greater part of his days either at Rome or Bologna.

Of Turin.

In the XVIIIth century we find a School established at *Turin* by another distinguished native artist, namely, *Claudio Beaumont*, by whose means and interest a Royal Academy was first established in the Capital; some of his Pictures are to be seen at the Church of Santa Croce and in the Royal Library.

DUTCH AND FLEMISH SCHOOL.

In turning our attention to Holland and Flanders, we find certain peculiar and distinctive qualities belonging to the Painters of these countries, and a perfectly new department of Art established; new, at least, in comparison with that which we have hitherto been reviewing, and indeed invented, one might almost say, by the rude Ultramontanes. It is a style of a lower description; it aims at a more homely representation of Nature than that which the polished Italians had ever thought worthy of being represented on canvass; but still it is excellent in its kind. Whether Figures, Portraits, or Landscape are subjected to the pencil, strong characteristic expression everywhere gives an interest to the scene; and Nature is vividly brought before our eyes: neither is skill nor science wanting, nor are the picturesque refinements of colour, grouping, or striking effects of light and shade, by any means absent from the better style of Dutch and Flemish Pictures; on the contrary, their artists have laboured long, both judiciously and industriously, and now exhibit all the advantages which the most accomplished practical experience can expect to attain. All that can fairly be objected against them is, that they possess no refinements of dignity, or loveliness of attitude; none of the tempered delicacies of sentiment are ever expressed by the personages whom they represent in their compositions; it is Nature—plain Nature—and Nature, too, as she shows herself amongst the ruder nations of the North; unadorned, and unassisted by those Poetic feelings which in realms of higher polish and civilization have ennobled Mankind.

Van Eyck.

This School dates its existence from the days of *J. Van Eyck*, the reputed inventor of Oil Painting, and of his brother, *Hubert*, both of whom passed their lives at *Ghent* and *Bruges*. Two fine Pictures by the former of these artists are in the possession of the Duke of Devonshire, and in them may be traced the first symptoms of that distinctiveness of feature and attitude, which was to be regarded in after-times as the peculiar characteristic of the School. As to the invention of the art of Painting in oil, it is clear that it does not belong to Van Eyck; many Pictures in Italy, and even in England, were so painted long before his day: but he certainly made some great discovery with regard to the use of oil as a vehicle (as it is called) for colour, and it is probable that his secret may have regarded the preparation of a drying oil for the Painter's use; than which, indeed, no discovery can be conceived of much greater importance, as far as regards the mechanism of Art; nor need we be surprised at the sensation which it created both in Flanders and in Italy. On this subject we may refer to James's *Flemish and Dutch Schools of Painting*.

His discoveries in oil painting.

J. Van Eyck was born in 1370. Contemporary with him was *Hans Hemmelink*, who, though he mixed his colours in the old fashion, with white of eggs or gum, obtained much harmony and power of colouring. He too was of Bruges.

Hemmelink

Volkaert Klaasz.

We next come to *Volkaert Klaasz*, of *Haarlem*, chiefly celebrated for his designs for the Painters on glass; an Art for the invention of which we are indebted to a Frenchman, (*Gulielmo de' Marcilla*, or *William of Marseilles*,) as appears, but which was nowhere carried to so great perfection, or so extensively practised, as in Flanders. In all the Pictures of Klaasz we observe sober-looking, sedate figures, placed in angular and awkward attitudes, and yet by no means void of force or expression. The same remark may be made of two other Painters of an early date, *Quintin Matsys*, of Antwerp, a name well known in England, from his celebrated Picture of the *Misers*, at Windsor Castle, and *Cornelius Enghelbrechtsen*, (or *Cornelius le Cuisinier*,) of *Leyden*, so called from being cook in his own family; he was greatly patronised by Henry VIII. of England, and his works were highly esteemed in this country.

Jacobs.

But *Leyden* has still higher claims to notice in a Historical account of this School, from being the birthplace of *Lucas Jacobs*, (or *Lucas de Leyden*,) the friend, and we may add, in some sort, rival of the celebrated Albert Durer. He was an Engraver, Painter on glass, as well as Designer of Landscape, History, and Portrait, and excelled in all these several departments of the Art; some of his engravings, which are by no means uncommon, will give a better idea of his style than can be furnished by any verbal description. Still, however, the School furnishes no examples of more spirited style than those which have been described; nor does it exhibit any great advancement in the ideas of its professors on the subject of their Art.

Progress during the XVIth century.

About the beginning of the XVIth century a considerable change seems to have taken place; the fame of the Italian Painters, which had now reached its zenith, the universal admiration which they had excited, and the overwhelming praises which were accumulated upon them by all the writers of the day, induced these northern artists to enlist themselves under their banners, rather than, as bolder spirits would have suggested, to enter into competition with them. Most of the Dutch and Flemish artists of this century thought it absolutely necessary to visit Italy, in order to qualify themselves for the exercise of their profession; and their own natural powers and natural resources were neglected, in the hope of sharing the fame of the Italian School. Hence arose a new style of Painting, not indeed a very successful one, but it may be described as approaching nearer to the reigning fashion of the day in Historical composition, than any thing that the artists of this School had hitherto produced. *Lambert of Liege* was one of these travelled artists, and one who contributed more than any other, perhaps, to foster and to encourage among his countrymen this rising predilection for Italian study. He established for himself a School on the Italian principle, in which were formed many of the better artists of the succeeding Age; *William Key*, of Breda, who is said to have painted both History and Portrait in good style, gained his instructions here; as did also *Hubert Goltzius*, of whose proficiency we can form a good idea from his engravings now extant. Last, not least, we may quote the name of *Franc Floris*, (or *Francis d'Uriendt*,) to whom is attributed, even by a Florentine writer, (Vasari,) the surname of the Flemish Raffael: it must be confessed, indeed, that in point of the Classical air with which he has invested his figures, he went far beyond any of those Painters of the Low Countries whose names have been mentioned above. *The Life of St. Luke*, and the *Day of Judgment*, painted for a Church at Brussels, are reckoned among his best works. We may be enabled to form some judgment of the esteem in which he was held by his countrymen, from the number of young artists who crowded the benches of his School, each desirous to begin the world under the auspices of so celebrated a name: his scholars were a hundred and fifty in number, amongst them were his two sons, *J. B. Floris* and *Franc Floris*, *Martin Vos*, *Lucas de Heere*, (who was much employed in England,) *Old Frank* and his family, and *Porbus* and his family, who both seem, like the Bassano family in Italy, to have cultivated a style that was hereditary in descent together with the name of their family.

Franc Floris.

His scholars.

The city of *Brussels*, too, may exult (and it is no small matter of boast) in having contributed one of the artists who formed the School of Raffael at Rome, *Bernard Van Orlay*, or *Barent of Brussels* was his name. His most celebrated original compositions were *Cartoons* for the tapestry of the Palace of the Prince of Orange at Breda; but both he and *Michel Coxcie*, of *Mechlin*, who also had studied in Italy, were most successful in their copies and *pasticcio* imitations of the Pictures of Raffael; many of those bright and soft Paintings, which are now highly valued as undoubted originals of that great master, having in fact issued from their manufactory. *Il Sordo Barent*, as he was called in Italy, was the son of *Van Orlay*, but a follower of the style of Titian rather than that of his father. We find a few other Historical Painters of note at Brussels, as *Lucas Gassel von Helmont*, *Peter Moel*, and *Roger de Weyde*.

Barent.

At *Utrecht* we meet with *Jan de Mabuse* in high reputation towards the middle of the XVIth century. At *Amsterdam*, *Jan Schoorel*; and *Antonio Moro*, the pupil of this last-named artist, rose to so high a reputation as a Portrait Painter, that he received invitations to foreign Courts, and was treated with the highest attention at London, Madrid, and Lisbon; a great honour for one who was not a native of Italy, hitherto regarded as the natural and exclusive country of the Fine Arts.

ainting.

Though the Italian taste, and a general rage for Historical Painting had now completely gained the ascendancy in public estimation even in Holland and the Low Countries, yet we turn with pleasure to that raciness of native talent, which here and there appeared to recall the natives of these countries to a just appreciation of their own natural peculiarities. The Heroic vein never seems to have been adopted, willingly at least, either by the Dutchman or the Fleming; they are in this line imitators, and awkward in their imitations. It is only when we see from his spirit and vigour that a man is following a natural call and inclination of his genius, that we can allow to him a full tribute of praise and admiration. The first master who struck out a new line, and thus boldly dared to leave the fashionable and beaten track, was *Peter Breughel*, or *Breughel the Old* or *the Droll*, as he is called; not but that he, too, has painted Historical pieces, in compliance with the fashion of his day; but it is in his lighter pieces alone, such as fairs or *kermesses*, marriages of the peasantry, and other rustic revelries, that we recognise the full force and power of his talent. He painted first at Brussels, and next at Antwerp, and left behind him two sons, who attained great eminence in their respective lines, *P. Breughel the young*, (or *Breughel d'Enfer*,) a Painter of conflagrations, &c., and *Jean Breughel*, (or *Breughel de Velours*,) so named from the bewitching softness of his style.

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reughels.

Aertsen.

Peter Aertsen, (or *Peter the Long*,) who was born at *Amsterdam* in 1519, may be regarded as an inventor with regard to another branch of Art, namely, the Painting pieces of still life; a walk of Art that may be said to have been carried by the Flemish and Dutch artists to the highest degree of perfection: pots and kettles, and other kitchen furniture, in the hands of Aertsen became materials for a Picture; and with him they were made to produce a beauty of colour and effect equal to that which might be exhibited in the best executed Pictures of more promising imagery. His style presently attracted notice, as much from its intrinsic merit as from its air of novelty, and was followed with great assiduity by many succeeding artists, such as *P. van Bochts*, *W. Kalf*, *T. Dicht*, *Peter Arnold*, and *Dirch Pieters*, &c.

A third walk of Art, which now came into cultivation in these countries, was the Painting *perspectives*, or architectural vistas; but by the Dutch the rich combinations of Gothic architects were exhibited, not, as by the Italians, the symmetric and rectangular forms of the Grecian or Roman buildings; a most important difference in the eye of the Painter. The sublime effects of *chiaro-oscuro*, which these gloomy piles of building afforded, and the mellowness of their colouring, invited men of high talent to employ their time in their delineation; and it may be stated with truth, that there are few compositions wherein more skill and ability is shown, than in the Pictures of Churches produced by this School. *Jean de Uries*, a native of Friesland, born in 1527, was the first to commence this line; it was carried to a still greater degree of perfection by his scholar, *H. Steenwych*, and again, in after-times, by one who was the scholar of the last-named, that is, *Peter Neefs*.

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Some successful attempts also were made at this day in the department of Landscape Painting by *Molenaer*, *Matthew*, and *Paul Brill*, who are, or, at least, the two last are, better known at Rome than in their own Country. Marine views also, for which this School became in after-times so celebrated, were painted even in this early day by *N. Cornelius Vroom*, the same artist who furnished the designs for the tapestry representing the defeat of the Spanish Armada, now hanging up in the English House of Lords.

Dutch and Flemish School.

Marine views.

There is no branch of Art, perhaps, in which this School showed so much real merit, as in Portrait painting; there is an apparent breadth arising from their Portraits, a management of their subject, and an air of fidelity of character preserved in all their works of this nature, which were beyond praise. *Cornelius Ketel* and *Mirevelt* are both well known in England in this line. Many others obtained establishments at foreign Courts; nor ought we to consider Courtly favour as limited to professors of this branch alone, when *Bartholomew Spranger*, for his Historical designs chiefly, was employed both by Pope Pius V., at Rome, and the Emperor Maximilian II., at Vienna, from the latter of whom he received a patent of Nobility.

Ketel.

Mirevelt.

Spranger.

But neither was the rage for the style of Italy subdued, nor were the Dutch and Flemish artists less desirous than before of finishing their education in that Country: there was, indeed, formed, towards the end of the XVIth century, a very large Society by them, during their residence at Rome, under the title of the *Bande Académique*. They had regular meetings, accompanied with ceremonies and libations in somewhat a freer style than that to which the Italians are accustomed, but they imitated the example of that people, in giving a *sobriquet*, or nickname to every one of their countrymen, upon his first admission to their Society, by which he continued ever after to be distinguished amongst themselves.

Bande Académique.

Dionysius Calvart, of *Antwerp*, may be mentioned as one of the most noted of the Dutch Italian Painters. His native country may be justly proud of him, as he was the first ultramontane who was regarded as eminent enough to establish a School of Painting in Italy. It was in his School at Bologna that Guido, Domenichino, &c., studied, before they attached themselves to the maxims of the Caracci.

Calvart.

In the works of *Otto Venius*, the master of Rubens, we see a fair specimen of the Classical turn which had been acquired by these sons of the North, and the progress they had made. His *Emblemata Horatiana* abound with designs conceived with as much taste as spirit and ease.

OttoVenius.

Henry Goltzius was a master scarcely less successful in his way. *Adam Van Ort* also may be mentioned here, and his pupil, *H. Van Balen*, of Antwerp, many of whose elegant and spirited little figures will be remembered by the Italian traveller, as holding a distinguished rank among the marvellous productions of that Country. Among his pupils were *Sneyders* and *Vandyke*.

Goltzius.

Van Ort.

Van Balen.

A. Bloemart is a still more singular instance of the labour and zeal with which Italian studies were pursued at this time: in his compositions we see a grandeur of thought, and a noble simplicity, far beyond the usual productions of the imitative class; from his turn of thought he would have done credit to the School of Rome herself, and yet, as far as we know, he never left the boundaries of his native land, and framed himself wholly by the models and examples which were afforded

A.Bloemart.

in the Academies of the Dutch and Flemish cities, and the private cabinets of connoisseurs.

Rubens.

But we now touch upon the most brilliant period of the Dutch and Flemish School: all that had hitherto been displayed in Art in these Countries, was to disappear before that bright constellation of masters, which beamed forth in its full lustre in the course of the XVIIth century. Of these, the first and greatest is *Peter Paul Rubens*. So wondrous was the merit of this extraordinary man, that he seems to have advanced the condition of the Professors of the Art itself to higher honours than it had hitherto been thought worthy to bear. He was invested with singular distinction, and, (though without relinquishing his regular professional occupations,) was often selected for employments of a diplomatic nature. In Italy, Spain, and England, he was known and accredited, either publicly or privately, as a negociator; and in all these Countries he has left specimens of his talent which are to this day held among the most precious and most valuable of their treasures. The series of Paintings representing the Life of Marie de Medicis, in the Louvre at Paris, and the ceiling of the Banqueting-house at Whitehall, in London, may be mentioned as splendid examples of his style, though there is no private collection of Pictures throughout England that does not boast some of his works. Though, as it should seem, without any perception of grace and beauty, he still is considered to have excelled in more points of the Art than almost any other Painter on record, except Corregio: there is an exuberance of design, a floridness of colour, and a general richness and fertility of invention, pervading all his works, which fill the mind, or rather, we should say, overwhelm it, with their power and prodigality. To give an idea of the marvellous extent of his talent, it is indeed enough to say, that he painted History, Portraits, Landscapes, Animals, &c., all with a degree of facility and spirit that was excelled by none of his contemporaries.

His followers.

We may readily suppose that a man who moved in so elevated a sphere, and became for a time the idol of the Public, would be followed by a host of imitators, and so it eventually turned out; the names of some of the more eminent are worth recording, because their Pictures are often confounded with those of Rubens himself. We may mention, therefore, *Erasmus Quellin*, of Antwerp, *A. van Diepenbeke*, *Theod. van Thulden*, *Jan Thomas*, *Fr. Wouters*, of Liege, *J. van Oost*, *J. van Koeck*, and last, though far more eminent than all the others, *Vandyke*.

Vandyke.

His followers.

Antony Vandyke, as well as his master, Rubens, was very favourably received at the Court of Charles I. of England, and has left in our country very many beautiful specimens of his inimitable style of Portraiture. Scarcely were his talents more justly appreciated, or his works more generally admired, during his stay at Genoa, or in other parts of Italy, than they were in London. He is an imitator, doubtless, to a certain extent, of Rubens, in his style of colouring; but in his Historical compositions, in the attitudes and postures of his figures, there are peculiarities that afford, even to an unlearned eye, the easy means of distinguishing between the works of the two Artists. Vandyke had many scholars and imitators, such were *Bertrand Fouchier*, *Adrian Hanneman*, *Jean de Reyn*, and *David Beck*, of Delft; the two last of whom, it may be important to add, resided many years in England.

Dutch and Flemish School.

Sneyders.

Jordaens.

Seghers.

David Teniers.

We have before stated, that the middle of the XVIIth century was the proudest era of the Flemish and Dutch School, and it seemed as though, by the collision of contemporary geniuses, a light was then kindled which illuminated for many a year all the Transalpine seminaries of Art. *Francis Sneyders*, who was sometimes employed as an assistant of Rubens, painted animals with a spirit and fidelity which, since his day, have never been equalled. *Jacques Jordaens* laboured in the Historical department with a degree of success only inferior to Rubens himself. *Daniel Seghers*, by his inimitable taste and skill, introduced a taste and fashion for a hitherto despised line of Art, namely for Flower painting; and he may be considered as the father of that School, which in aftertimes gained so much celebrity in Holland and the Low Countries. *David Teniers* too, the elder, whose son became in the next generation so celebrated for his Pictures, cultivated that taste which was before said to have been originally introduced by Breughel the Droll, namely, the characteristic scenes of common life. All these great Painters were then stationary at *Antwerp*, and thus this city gained a name as a nursery of the Art.

At *Brussels* we find *Breughel de Velours* enjoying a high reputation for his small pieces in Landscape and History. *Philippe du Champagne*, an artist better known in France than in his own Country, was a native also of that city. *Francis Hals*, of Mechlin, too, belongs to this day, who painted Portraits in so excellent a style, as to be regarded by general estimation as no unworthy rival of Vandyke.

Cuyp.

Honthor

Esaias Vandev

Nor were the United Provinces less fertile in talent at this period; *Albert Cuyp*, of *Dort*, is unquestionably the best Painter of natural Landscape, such as it appeared within his own Country, that ever existed. While from *Utrecht* came *Polenburg*, so celebrated for his cabinet Pictures; *Gerard Honthorst*, (or *Gherardo delle Notti*, as he is called in Italy,) the happy imitator of Caravaggio; and the family of *De Heem*, so far famed for their Paintings of Flowers. *Haarlem*, too, at the same time, contributed her quota of genius, and boasts of *Esaias Vandevelde*, the first of that family afterwards so well known in England; and that most indefatigable of all artists, (if all Pictures bearing his name are really from his hand,) *Van Goyen*.

Rembra

But it is to *Leyden* we must turn our eyes, if we would behold the chief glory of the Dutch School, namely, *Gerrets*, or, as he is more commonly called, *Rembrandt van Rhyn*.

Of all men who have ever devoted their time and study to the Art of Painting, Rembrandt may, perhaps, lay the highest claim to originality of genius. Scarcely does he seem to have gained the mechanism of his Art from the three masters under whom he studied in succession, before he quitted them, and shut himself up in his father's mill, where he became, by his own labour and study, a finished Painter of first-rate merit, the founder of a new School, as it were, and a new style of Art. His novel and very imposing method of managing and concentrating the light, in all his compositions, first attracts our attention: then we observe with amazement the variety of colour produced by his deep transparent tints, enlivened here and there with the aid of touches of extraordinary vigour: the whole composition harmonized and united by the use of a greyish greenish background, of an invention peculiarly his own. Add to this, a truth of character and expression in his figures, which though conceived in the same taste as those of many of his fellow-countrymen, yet were distinguished from them all by their superior force and strength. Hence one may form some idea of the magical effects of a genuine Picture by Rembrandt. Disdaining all learning, and despising the then fashionable study of the antique models, with which, indeed, he never gave himself the trouble to become fairly acquainted, he seems to have attained the *ne plus ultra* of the Dutch Heroic style, if any Dutch style may be so called.

Like many other persons of strong but half-cultivated minds, he had his humours and eccentricities of character; and they showed themselves even in his Painting room: nor can we deny that these too were made eminently subservient to the peculiarities of his style. For instance, his cabinet was filled with what he called his antiques; tin pans, brass pots and kettles, and rubbish of every description; and from these, as from the cabinet of a virtuoso, he supplied the materials requisite to fill up his Historical compositions. The single hole or crevice, through which alone the light was admitted to this apartment, furnished him with his ideas of *chiaro-oscuro*, and aided his conception of those singular effects which he produced, both in his Pictures and his etchings. Some have fancied that this conceit was originally suggested to his mind during his days of study in his father's mill, which was probably thus lighted by a single small window; yet, though this idea seems plausible enough, it may have been that his practice in this respect was the result of the deepest reflection. When it is considered, that a Picture is meant to represent, not the whole view around us, but, as it were, the fraction of any scene presented in Nature, who shall say that Rembrandt did not in this way seize upon the most perfect principle of the picturesque, as it regards the effect of light and shade, that we yet have known? Does it not, indeed, appear to be the refinement of an artifice, in these graphic representations, of which some symptoms may be traced in the works of all our best artists?—Rembrandt's etchings bear that value with the world of cognoscenti which the touch of genius ought to stamp upon them; and they did so even in his lifetime. Though we are bound in justice to add, that this very circumstance induced him often to resort to a mean and base trick, in order still farther to impose on the generous partiality of the Public: for he would bring them out sometimes in a half-finished state, and sometimes with false dates of place, and such other unartist-like deceits, as prove too fully that his moral principles were no less removed from any correctness of rule, than his eccentricities of manner were from the common practices and prepossessions of his fellow-creatures.

Rembrandt had, as may be expected, a large School of imitators, many of whom were eminently successful. We may quote the names of *Jurien Ovis*, *Ferdin Bol*, *Adrian Verdoel*, and yet still more celebrated, *Eeckhout*, *Hoogstraaten*, *Nic. Maas*, *Sir Godfrey Kneller*, and *Gerard Dow*.

Gerard Dow, like all true men of genius, not content with following Rembrandt's manner, brought to his work something of his own: he adopted that which best suited his own peculiar talent, and, by adding a new style of colouring, became in some degree himself the founder of another School of Painting. His Pictures, which are of a small size, and exquisitively finished, are generally composed of single figures; they are beautiful models of the Art of colouring. He generally introduces a carpet, for the sake of the richness of its varied hues, or sometimes, perhaps, to bear out by its brilliancy what might, in other parts of the scene, appear too fine and gaudy. *Mieris* was his scholar; an artist of great simplicity of taste, as to colour, but in all respects a worthy disciple of such a master: he painted Portraits for the most part, but they too are always of a small size.

Dutch and Flemish School.

Mieris.

Haarlem produced two very celebrated men, who were born in the beginning of the XVIIth century: namely, *Gerard Terburg*, an admirable Painter of cabinet Pictures representing scenes in common life; and *Adrian Brauwer*, a profligate and incorrigible drunkard, who, nevertheless, possessed great talent, though he seems never to have entertained a thought of looking out for subjects for his pencil, beyond those drunken scenes with which his libertine life made him daily conversant.

Terburg.

Brauwer.

Adrian and *Isaac Ostade*, whose names are also celebrated in this same walk of Art, were natives of *Lubeck*, in Holstein; but since they formed themselves chiefly by their studies at Antwerp, and as they lived in Holland for the most part, may be fairly included among the Flemish and Dutch Painters. Though the School will lose almost as much by the adoption of this rule in another instance as it will gain in this; for an artist of great reputation, namely, *Peter de Laar*, (or *Bambòccio*,) a native of these parts, not only studied in Italy, but passed the greater part of his life there, and therefore may be classed among the Italians. He it was by whose skill a taste was introduced into that Country for these ultramontane humours.

Adrian and Isaac Ostade.

Bamboccio.

We have now arrived at another generation, when the sons of the earlier contemporaries of Rubens were coming into vogue; and among these we find the name of a Painter who certainly, next to that great man, has most contributed to the fame of his Country, namely, *David Teniers the younger*. He was an admirable Painter of Landscape, and equally successful, for one cannot say more so, in his representations of fairs, conversations, shops, and subjects of that homely description; in which it is difficult to decide, whether one should admire most, the discrimination with which they are treated in respect of character, or the skill and artifice displayed in their colouring, arrangement, and design.

Teniers.

Of Landscape Painters, we may mention *Herman Swanevelt*, (the hermit of Italy, as he was called,) a Dutchman born, who at Rome became a scholar of Claude Lorrain; and *A. Pynaker*, of *Delft*, who also wandered to Italy, and completed his studies there. Much more celebrated was *Nicolas van Haarlem*, or *Berghem*, as he was nick-named, a pupil of *Van Goyen*, and one who, like his master, had the special merit of limiting his views to those subjects which the country around him naturally supplied, instead of migrating to the less congenial land of the south. His style is remarkable for the clearness and freshness of his colouring; and it is enough to say that, all Dutchman as he was, he is universally acknowledged to have been the best Painter of pastoral scenery that ever appeared. True genius finds matter enough to work upon, wheresoever it may by chance have been placed.

Swanevelt.

Pynaker.

Berghem.

From the same city came *J. Wynants*, also an excellent Landscape Painter: his Pictures are conceived certainly in a more lively, but still a more finical style.

Wynants.

Ruysdael.
Hobbema.

Jacques Ruysdael, too, was from the same place. This last artist, as well as his contemporary, *Hobbema*, of *Antwerp*, makes use of the same brown ground for a middle tint, of which Van Goyen had so happily availed himself. Their Pictures seem, indeed, generally, little more than a few touches of opaque colour upon this transparent brown, relieved occasionally with black. The forest scenery of these two artists is always excellently depicted.

Wouvermans.

Philip Wouvermans was also of *Haarlem*, and one of those unhappy men who met with success in his life-time very ill-proportioned to his real deserts. That taste which inclined him so to compose his Pictures that his horses, not his Landscape, caught the eye, and formed the main feature, was, indeed, peculiar to himself alone: and it must be observed, that in this, and all cases of a similar nature, it is absolutely necessary for the artist to be able to create a taste in the Public for this species of Painting, and to enure them to it before any great demand for his Pictures can possibly arise; and this is seldom done without the intervention of a Patron.

Paul Potter.
Karl du Jardin.
Weeninx.
Vandevelde

Far different was the fate of *Paul Potter*, of *Amsterdam;* with him, indeed, cattle were not merely brought forward so as to be prominent from their situation, but actually formed the chief part of his Pictures; his Landscape was but an accessary in the style of composition which he adopted: and he filled the same place with regard to representations of the domestic animals, which Sneyders did with regard to the wild; nor was he less successful in his delineations of their character, than that great artist had been in his line. They were painted with surprising fidelity of manner and expression. Even during his lifetime, though this is less extraordinary in those golden days of patronage, every Picture that he wrought, however homely the subject, was bought with the greatest avidity; and an extensive catalogue of imitators preserved the memory of his style long after their inimitable master was gone. Of these *Karl du Jardin*, also a native of Amsterdam, was, perhaps, the best: he was an imitator, however, and a successful one, too, of Berghem as much as of P. Potter; and still, with all this servile power, he possessed much original talent of his own. Some other distinguished natives of Amsterdam occur towards the middle of the XVIIth century; such as *Weeninx*, (both father and son,) admirable Painters of Landscape and of Game. Likewise *Eglon Van der Neer*, a Painter of Moonlight pieces, and *William Vandevelde the younger*, a Marine Painter. *W. Vandevelde the elder* was a native of *Leyden;* and both passed the latter part of their lives in that city.

Both.
Zacht-Leven
Schalken.

Utrecht boasts at that time two couple of brothers who greatly excelled in Landscape Painting, namely, *Jean* and *André Both*, and *Herman* and *Cornelius Zacht-Leven*. But Portrait Painting seems to have met with most encouragement from the wealthy; and the rage of the day seems chiefly to have been for small Pictures. Mieris introduced this fashion, and it was now kept up by *G. Metzu*, of *Leyden*, whose colouring may be said to approach in small, very near to that which Vandyke produced in large. *Godefroy Schalken*, of *Dort*, famous for his candlelight compositions, was much engaged also in Portraiture; and so was *Jacques Denys*, of *Antwerp*, though he ventured also into the Historical line, and raised himself so great a reputation in Italy, that he was received on his return to his native city with a public procession in his honour.

Dutch and Flemish School.
Van Blo men.

We are not to suppose that Historical Painting was wholly neglected in Holland and the Low Countries, during this latter period of the School; but the truth is, that those artists who struck out the brilliant novelties of style which form the real glory of the Flemish and Dutch Schools, have so far eclipsed the Classical and imitative band, that those who would give a true and just idea of its History must limit their account to the former. We can mention only one artist of these parts whose ideas seem to have been really naturalized in the soil of Italy, and that was merely in the line of Landscape, namely, *Van Bloemen*, or, as he is commonly called, *Orisonti:* every other artist seems to have sunk in reputation, the farther he attempted to advance in what was to him neither natural or congenial.

Lairesse.

Gerard Lairesse, of *Liege*, is called the Flemish Poussin, and few men ever displayed more fertility of genius than he did; but unfortunately, like many of his compatriots, his sensual indulgences brought upon him a severe misfortune, and he became blind in the fiftieth year of his age.

Vander-meulen.
Hughten-burg.

Battle Painting was now grown very much into vogue: *Vandermeulen*, of *Brussels*, was one of the most eminent in this branch; an artist who had the good fortune to be employed by Louis XIV. of France, in order that he might immortalize by his pencil the military exploits of his reign: *Hughtenburg*, of *Haarlem*, (his scholar,) also followed him in the same style of Painting, and he celebrated, on the other side, the glorious actions of Prince Eügene of Savoy, and the Duke of Marlborough.

The Van Huysums.

The family of *Van Huysum*, of *Amsterdam*, in the beginning of the XVIIIth century, succeeded in carrying to still greater perfection than it had yet attained that style of Flower Painting which had excited so much admiration in the days of *Seghers*, *Mignon*, and *De Heem:* so great, indeed, was the passion which had grown up in Holland for the cultivation of flowers themselves, that the artists who made them the objects of their study were sure to meet with abundance of patronage, and therefore it ought not to seem surprising that many of the Pictures of the Huysums were sold at as high a price as 1000 or 1500 florins.

Vanderw

In the elegant and highly-finished Pictures of *Adrian Vanderwerf*, we trace a similar taste to that which formerly inspired the pencil of Polenburg; and it seems to be the only line in which any degree of elegance of form or attitude has been attained in the compositions of this School. His Pictures fetched immense prices even during his lifetime; for they were of a style that could not fail to be pleasing to all the world, from the wise to the vulgar. With regard to his style of attitude, &c., he may be regarded as affording a happy specimen of what may be called unclassical grace. He died in 1722.

The Painters of the modern Flemish and Dutch Schools are very successful in their imitations of their mighty predecessors; and though many men of ability have appeared amongst them, and even now are living, yet, perhaps, these imitations may be classed among the most happy productions of their pencil.

GERMAN SCHOOL.

ertDurer

s and
eenwald.

Nuremberg was the first city of Germany wherein a taste for the Arts of design appear to have been displayed. In the XVth century *Martin Schoenfield* was resident there, who is celebrated as the reputed inventor of the art of engraving upon copper: and there, too, flourished at the end of this same century *Albert Durer*, the chief leader of early Art in his Country. He was, as many other of the earlier artists were, a Professor of more than a single branch of Art, and gained a high reputation as a Painter of History, an Architect, a Goldsmith, and an Engraver. The correspondent of Raffael, the friend of Lucas de Leyden, and honoured towards the close of his life with a patent of Nobility from the Imperial Court, he may be regarded as having attained the highest honours and most extensive fame of any man of his time. His general style is well known, for his engravings are in the hands of almost every one: he possessed great force and even sublimity of design, but had, it must be confessed, little perception of grace or beauty. *Pens* and *Gruenwald*, whose Pictures may be seen in the Royal Gallery at Munich, and were contemporary with Albert Durer, afford no mean specimens of the professional skill of the artists of that early day.

as von
ller.

bein.

There was another artist of this period who was endowed with natural faculties much of the same stamp and order, namely, *Lucas von Muller*, (or *Kranach*,) of *Augsburg:* and something similar, in point both of ability and skill, was a person better known to us in England than any of the above, that is, *Hans Holbein*, of *Basle*. He is first recorded by the Chroniclers of the time, as having been engaged by the municipality of that city in furnishing Paintings for the Fish Market and the Town Hall of his native City; these were public works, and therefore, that he should be selected for the purpose, is some proof of the honourable estimation in which he was held. He also, as it appears, painted the celebrated *Dance of Death*, then a favourite subject of representation in Swisserland, and which has exercised the ingenuity of many Painters of allegory in a later Age. We can discern nothing now remaining at Basle of this work, or nothing rather which can, on any good ground, be credited as having come from his pencil. It was not until the period of his settlement in England, however, that his style was matured, or that his fame rose to its zenith. We learn that he undertook this journey upon the strength of letters of recommendation, of which he was the bearer, from Erasmus to Sir Thomas More; and so pleased was his patron with his industry and talent, that it was through his means that he finally received the appointment of Painter to King Henry VIII., and was established as a favourite of the Court. Besides painting numerous Portraits of our Nobility, Holbein was engaged also in making some large allegorical Pictures for the Surgeons' Hall in London; for the Bridewell Hall, and for that of the Merchants of the Steelyard: and it will be allowed, that he certainly was possessed of great power and fertility of invention, though nothing can be more remote from Classical grace than was his style. His Portraits, with which we are most familiar, carry with them the appearance of great truth and force of character, though chastened by a soberness and dignity, both in mien and attitude, which were peculiar in some measure to the manner of that day.

Tobias Stimmer, another Swiss artist of the XVIth century, furnished some very spirited and clever designs illustrative of the Sacred History, meant as accompaniments to an edition of the Bible. The manner of conception of these prints much resembles that of the works of Holbein and A. Durer. Toward the end of this same century we find abundance of Painters on glass, and some few authors of Historical pieces, as *Kranach the younger; Aldegraaf*, of *Nuremberg*, whose engravings are not uncommon; *Swartz*, of *Munich*, and *Haintz*, of *Berne*. We must suppose the Painters of this part of Germany not to have possessed any very great or extraordinary talents, when we find the Emperor Maximilian II. sending to a distant country for some decorative works which he had in contemplation, and employing *Bartholomew Spranger*, of *Antwerp*, for that purpose. Nor have we any reason to believe him to have been found unworthy of this preference, as he was continued in his employment during the reign not only of this Emperor, but also that of his successor, the Emperor Rodolph. Many of his works are still to be seen in the Churches of Vienna and Munich, &c.

Rottenhamer.

We now come to a native artist who does infinite honour to the Country that bore him, namely, *Jean Rottenhamer*, of *Munich*. He was an imitator of Tintoretto, both as to his manner of colouring as well as the general air of his compositions; and so successful was he, that he received commissions in many places for large altar-pieces for Churches, while he was no less sought after for his small subjects painted on copper, such as are not unfrequently to be found in England. But for his extravagance and profligacy, Rottenhamer probably would have amassed a large fortune by his labour. After his return from Italy he lived chiefly at Augsburg.

Lys.

While the South of Germany was thus comparatively fertile in the production of genius, we shall find some artists of eminence who came from the more distant and Northerly regions. Such was *Jean Lys*, a native of *Oldenburg*, who painted both in large and small size; History, village feasts, dances, &c.: he, too, like the last-named artist, was a great admirer and imitator of the Venetian colouring, and, like him, was thoughtless and profligate, and died in poverty.

At *Frankfort on the Main* were born *Adam Elsheimer*, in 1574, an excellent Painter of Historical pieces of small size, and in 1606, *Sandrart*, the Historian of the Art. Portraiture was the chief employment of this last-named master, and he made his residence at different periods, in Bologna, Frankfort, Amsterdam, Augsburg, and Nuremberg. *J. Lingelback*, the Painter of market-places, marine views, &c., was also a native of this place.

Claude
Lorrain.

Among other Painters of the XVIIth century we must mention *J. W. Bauer*, of *Strasburg*, the author of designs for Ovid's *Metamorphoses:* and next, one who, as far as locality of situation is regarded, ought to be classed among the German artists, namely, *Claudio Gelée*, or, as he is commonly called, *Claude Lorrain:* for that Province was not at that time annexed to France. His studies, however, were made, as his fame was gained, on the Italian soil; and every touch of his magical wand, every shade of his rich and sunny Pictures, savours of a taste that can only be acquired by a residence in that delicious country.

There are many other native Germans of this century who are usually classed under the head of other Schools than this, on account of the eminence they attained after they quitted their parent land. *J. van Bockhorst*, (*Langhen Jan*,) a native of *Munster*, an excellent Painter of Portraits and Sacred History; *Adrian* and *Isaac Ostade*, from *Lubeck*, celebrated Painters of grotesque subjects and low life; *Henry Roos*, a pupil and imitator of Du Jardin, who was born in the Lower Palatinate; *Louis Backhuysen*, of *Emden*, a Marine Painter; *A. Mignon*, of *Frankfort*, and *Ernest Stuven*, of *Hamburg*, Flower Painters; also *Gaspar Netscher*, of *Heidelberg*, an inimitable Painter of Portraits of a small size, are all of them in common conversation attributed to the Flemish and Dutch School: to which, as far as they were artists, it must be allowed that they belong.

Adrian and Isaac Ostade.

So, again, *F. Moucheron*, a Landscape Painter, was a native of *Emden*, who passed most of his life at Paris and Amsterdam. *Philip Roos*, (*Rosa da Tivoli*,) a native of *Frankfort*, who combined pastoral scenes and architectural ruins, in his rapid and spirited method of Painting, so as to form admirable Pictures; yet he is usually ascribed to the Italian School, having chiefly lived in Italy. And *Peter Vander Faes*, or, as we call him, *Sir P. Lely*, became so naturalized in England during his long residence here, and is so much identified, by means of his Portraits of our great personages, with the History of our Country, that one is surprised to find that he was not a Briton, but a native of *Soest*, in Westphalia. The same remark may be made of *Sir Godfrey Kneller*, who was born at *Lubeck*, in 1648. Yet, in spite of these numerous examples, it must be said, that it was not for want of patronage at home that these artists could be fairly said to have been driven from their Country; for not only the Emperor of Germany, but most of the German Princes laid out large sums at this period in the purchase of Pictures; and many of them retained artists in their service, and advanced them to titular honours, as well as rewarding them with liberal pensions. The Courts of Hesse Cassel, Munich, Dusseldorf, &c., were always open to Painters of merit and renown. But the fact is, that there was no common centre of union in Germany among the artists themselves—no common tie—no general place of meeting for kindred minds; and Germany under that single name, dismembered as it is, and has been, is in reality no Country at all for any man. It includes a number of People speaking different dialects of the same language, but having in no other respect a community of feeling.

Lely.

Kneller.

In the next century, we may mention the names of *Raffael Mengs* and *Zoffani*, native Germans, who lived in Italy; *Lutherburgh*, of Alsace, and *Angelica Kauffman*, a Swiss, who expatriated themselves in a similar way, and bestowed, the three last at least, many years of their lives upon England.

Mengs, &c.

In returning to our notices of Southern Germany, we must not omit the name of *Paul Ferg*, a native of *Vienna*, who died in London, in the year 1740, many of whose pleasing compositions of Landscapes, and pieces with figures, are often to be met with at this day. There was also *J. Elias Ridinger*, a native of *Ulm*, a Painter and Engraver of extraordinary merit: though the line in which he exerted his abilities is one that does not equally excite the admiration of all people; he painted animals, and chiefly those of the chase.

Denner.

Balthasar Denner belongs also to the XVIIIth century, an indefatigable Painter of human heads: one whose works are so highly finished, that they would bear the critical inspection even of a microscopic eye. We might call this, however, but a vulgar style of Painting, when placed in comparison with the works of genius which we have heretofore been enumerating. He was, nevertheless, greatly patronised by almost all foreign Courts, and received offers of pensions and establishments in more instances than one, which his spirit of independence induced him to refuse. It must still be allowed, that in these Paintings, however minute the attention paid to details, the general character and the air of the whole was never forgotten: and his tone of colouring is sometimes very beautiful.

Spanish School.

Painting is much patronised at the present day in Germany, not only in the Imperial and Royal Courts, but in many of the minor States: and there are large Galleries formed from the works of the best masters, as well as public Academies instituted at Vienna, Berlin, Munich, Dresden, Stuttgard, and many other of the chief cities of Germany.

SPANISH SCHOOL.

The dominion of the Moors in Spain, and the rich and gaudy style of ornament with which their Palaces and Temples abounded, gave a turn to the Arts in this country, which rather retarded than assisted their progress; or, at least, prevented the Spaniards from acquiring so early as the Italians had done, the just and simple principles which ought to regulate public taste in this respect.

And when their attention was once awakened on this point, they were for the most part obliged to have recourse to study in Italy, and thus to expatriate themselves for a time, before they could attain any very considerable eminence in this refined and difficult branch of Art.

The artists of Spain present themselves generally to our notice, under the head of three different Schools, namely, those of Madrid, Seville, and Valencia; in which, if no very strong and distinctive peculiarities are to be observed, as characterising their several styles, yet the series of artists which are commonly attributed to other places, warrant us in making such a distribution here in a Historical point of view.

Madrid.

School of Madrid.

There were in *Madrid* several Painters who attained some degree of celebrity even as early as the XVth century; and a few of their works, indeed, are still preserved for the inspection of the curious, affording interesting examples of home-bred talent and industry. Such was *Antonio del Rincon*, a native of Guadalaxares, born in 1446, the first Painter who is said to have ventured to abandon the dry, timid Gothic manner of his predecessors, whoever they were, and to have made a nearer approach to the full proportions of the human form. His manner has a striking resemblance to that of Ghirlandaio of Florence; though, as it appears, this similarity arose from no other circumstance than their having made like efforts to improve their style, and from being placed in like circumstances. Both he and *Peter Berrequete*, (the elder,) were greatly favoured and patronised by Ferdinand and Isabella.

Antonio del Rincon.

P. Ber quete.

In the Pictures, again, of *Ferdinand Gallegos*, who was born at Salamanca, in 1475, we might fancy that we traced a strong savour of the manner and style of his great contemporary, Albert Durer; so much, indeed, does he resemble him, that it has actually been conjec-

Galleg

tured that he was placed under him as a scholar. Nor is it improbable, that Gallegos may have formed himself, to a certain extent, upon the published engravings of that master, which already had come much into fashion throughout Europe; as to any other causes of resemblance, we may, in the absence of more positive reasons, fairly attribute them, as we did in the last instance, to the natural similarity of efforts made by men of ability, when placed in similar and correspondent situations.

In the XVIth century the wealth which had accrued to the Spaniards, from their foreign commerce, and their enterprise in trade, paved the way for the establishment of the Fine Arts on a more brilliant and permanent footing; and, in the course of a few years, such talent developed itself, and such eminence was attained, as serves at this hour to shed infinite honour on the Schools of Spain.

erra. First may be mentioned the name of *Gaspar Becerra*, a native of Baeza, born in 1520. He was a pupil and assistant of the immortal Michael Angelo, at Rome; and, on his return to his Country, he painted many excellent Historical pieces in fresco, at Madrid, Valladolid, Salamanca, &c. The air of his style, as may be surmised, was like that of the master under whom he had studied; and the Italian tourist will, perhaps, call to his recollection with pleasure, a Picture by Becerra, in the Trinita di Monte at Rome. Nor ought the name of *Don Philip Guevara*, an amateur Painter, to be omitted here; he studied in Italy the manner of Titian chiefly; and there is no doubt, but that from his high rank, good taste, and natural ability, he materially contributed to the advancement of the Arts at Madrid.

vara.

Still more celebrated is the name of *Louis Morales*, or *Morales the Divine*, as he is generally called, either from excessive admiration of his talents, or, as some will have it, from the nature of the subjects which he painted. He first came into notice as a Painter at Valladolid, but his merit caused him soon to be invited to the Capital, where he found employment enough in the Palace of the Escurial, under the reign of Philip II. His ostentatious manners, however, were displeasing to the Court, in consequence of which he seems to have received his dismissal, after which he returned to spend the rest of his days at the city of Badajoz. His subjects are generally single figures, and are very remarkable for their excellent Drawing and force of expression, as well as for their peculiar chasteness of colour. *J. Labrador*, a Flower Painter, was his pupil. We next find a foreigner, *Pellegrino Tibaldi*, of Bologna, employed at the Escurial, in conjunction with *Barroso*, and two other native Spanish artists; indeed, the visits of foreign Painters seem at all times to have been frequent at this Court, and there can be little doubt of their having greatly influenced the fashion, (for such it is,) as to the prevailing manner of Painting at Madrid. We may next mention the names of *Pantoia de la Cruz*, a Painter of Portraits and History; *J. Batt. Mayno*, the master of *Cano*; and a still more celebrated artist in the line, namely, the Historical *Louis Tristan*. The last-named learned his Art, it seems, in the School of a Greek Painter, domiciliated in Spain, named *Theotocopulos*, whom, however, like some other precocious pupils, he soon surpassed in strength and power: his Pictures are remarked, in general, for their correctness of design, and their very harmonious tone of colouring; many specimens may be seen in the Churches of Toledo and Madrid.

ales.

istan.

F. Nazarrete *Fernandez Nazarrete*, or *el Mudo*, as he was called, was another native Painter whose talents were brought forward under the patronage of Philip II.; he painted Historical pieces with great spirit and talent, having studied in Italy, and formed his style chiefly by what he had seen in that Country.

Eugene Caxes. *Eugene Caxes* being a pupil of his father, who had formerly gone through a course of study in Italy, connects himself with the style of Painting in that favoured land, as it were, only by inheritance: but, nevertheless, he was a good Painter of History in fresco, and was much employed at Madrid, by those who seldom threw away their money, the members of Ecclesiastical establishments.

Velasquez. But we have now arrived at the period when appeared the greatest genius, in respect of the Fine Arts, that had yet dawned in Spain, namely, *Velasquez*, or, to give his name more at length, *Jacopus Rodriguez de Silva et Velasquez*. He was born at Seville in 1599, and was first initiated into the mysteries of the profession by Herrera, a Painter of that place; but he soon quitted his instructions for those of Frances Pacheco, a Historical Painter of far greater merit and celebrity. It is probable, however, that his ardent spirit caught more vigour from the sight of those numerous Paintings, which early in the XVIIth century were imported to Seville from Flanders and Italy, as well, indeed, as from Madrid, or at least, we shall otherwise find it difficult to account for the progress which he made. It is upon record, moreover, that the works of Tristan, whom we have mentioned above, particularly engaged his attention; and, so much was his enthusiasm excited, that in the year 1622 he left Seville, with the determination to go and seek his fortune, as well as prosecute his studies, in the Capital. His success in Portrait Painting soon established him there in easy circumstances, and finally led to his employment at the Court; and, owing to this engagement, he had the good fortune of being introduced to the acquaintance of the celebrated Rubens, who was at that time residing there. Of course, he received considerable advantages, if it were only from the conversation of so eminent a Professor, and the practice of visiting his Painting room. Still, however, dissatisfied with his progress, and anxious to improve himself to the utmost, he sought and obtained leave from Philip IV. to make a voyage to Italy, where the works of the great masters at Venice long occupied his time and his attention. Upon his arrival at Rome, he was received with distinguished marks of favour and attention by the Pope, so great already was his fame; and after renewing his studies in that city also, and employing his leisure hours in painting the likenesses of some of the distinguished personages about the Papal Court, he returned to Madrid in the year 1631. From this time he devoted himself to Portrait Painting, in which he attained such skill, that none but Rubens or Vandyke could produce Pictures fit in any sort to be placed in competition with his. Some years afterwards, Velasquez made a second journey to Italy, charged, it seems, with a commission to make a large collection of Pictures, Statues, and Busts, for the decoration of the Royal Palace at Madrid; which served as guides for the succeeding generation of the artists of this School. After this, we hear little more of him till his death in the year 1660.

No man certainly had so great an influence on the profession in Spain, or contributed so much to improve the ideas of his countrymen in general, both by precept and example, as Velasquez. As a Painter, indeed, of a natural style, he has rarely been surpassed by the greatest masters; while we may add, that his just distinction of distance, his brilliancy of effect, and the beauty and harmony of his colours, entitle him to a still less qualified approbation in the ornamental branch of the Art. With regard to the peculiar gracefulness of his touch, we need only quote the words of Raffael Mengs: "the pencil," he says, speaking of a Picture by Velasquez, "seems to have no share in execution here, it seems as a simple exertion of the will."

His pupils.

Martinez del Mayo, a Portrait Painter and Painter in water colours, was one of his pupils, as was *J. Carreno de Miranda*, a Painter of History in fresco, who also excelled in Portraits, and was in many respects a most successful imitator of his master. It is observable, that many Historical Pictures, and those, too, chiefly works in fresco, were produced about the middle of the XVIIth century, in Madrid, Valladolid, and other great towns, by *Matthew Cerego*, and *Claude Coello*. Of this last, who was greatly patronised at the Royal Palace, it is said by the Spaniards, that he united the design of Cano to the brilliant effects of Velasquez, and the colouring of Murillo; thus combining the excellencies of the chief heroes of the Spanish School. He is considered as being the last of the better class of Painters belonging to Madrid.

School of Seville.

Louis de Vargas.

Paul de Cespedes.

Herrera.

There is preserved in the Cathedral at Cordova a small picture of the *Annunciation*, painted upon wood by one *Pietro*, a native of *Seville*, and bearing the date of the year 1500. This is, however, merely a matter of curiosity; and though some other names of the same period are preserved, they only serve to prove that Painting was rudely cultivated in these parts even at that day. The first person of note of whom we have any account is *Louis de Vargas*, who was living at Seville in the former part of the XVIth century. He had made a voyage to Italy, it seems, and studied there under Perino del Vaga; and such was his proficiency in the line of History, that there are those among his zealous countrymen who compare him to Raffael. We have honourable mention made, too, of *Paul de Cespedes*, who was born at Cordova in 1538, and became eminent as a Sculptor, an Architect and a Painter in fresco. He went too, as others did in his day, to improve himself in his Art, by studying in Italy, and placed himself under some of the followers of Michael Angelo; and there are specimens of his pencil yet to be seen in some of the Churches at Rome. In 1577 he returned to Spain, on the occasion of being appointed to a Canonry at Cordova; and it was between this city and Seville that he subsequently divided the remainder of his days. L. de Vargas certainly possessed a more Classical turn of mind than any of the other Spanish artists, and we cannot deny him the merit of being a good colourist. But in speaking of the Spanish School, we must regard with still greater feeling of interest those who never had recourse to foreign study, and who formed themselves with a truly national spirit, from resources purely their own. One such Painter we find at Seville, in this period, namely, *Fr. Herrera*, (the elder,) many of whose Historical works are to be seen in the Churches at Seville. And, though, as has been already related, Velasquez disdained him as an instructor, the traveller in Spain recognises in him a degree of skill and talent which does honour to his country. It was his son who was patronised by Philip IV., and, though professedly a Painter of History, was so successful in still-life pieces, particularly fish, &c., that he obtained the name of *Il Spagnolo delli pesci*.

Cano.

Alphonso Cano was born at Grenada in 1601, and lived and painted chiefly at Seville, though there are few Churches or Convents in Madrid, Grenada, or Cordova, that do not possess some specimens of his pencil. He studied in Italy; and it is not uncommon to hear his works in Sculpture compared to those of Michael Angelo, and his Pictures to those of Albano; and from these expressions, though we may not be prepared to admit the justness of the application, we may yet be enabled to form some idea of his style and manner in those two lines of Art. We must also add, that, like some of the Florentines, he studied in a third department, and was a Professor of Architecture. He left behind him a very numerous band of scholars, and certainly must be considered as having greatly contributed to the success of the Arts in Spain. *Michel Jerome Cieza* is the one of his scholars who comes nearest to his master's style.

Zurbaran.

Fr. Zurbaran, the Spanish Caravaggio, as he is called, was born in 1598, and formed himself chiefly by copying the Pictures of that master which were to be seen at Seville, for he never travelled to Italy. His chief works are, the Pictures over the high altar in the Church of St. Thomas at Seville, the Paintings for the Convent of the Carthusians at Xeres, and the *Labours of Hercules* for the Retiro at Madrid. *Barnabi d'Arzala*, and the *Polancos*, were among his best scholars.

Moya.

P. Moya was born at Grenada in 1610, and first learned the principles of his Art at Seville; but in the course of his journey to Flanders, he saw some of the works of Vandyke, and thenceforth would study no other master; he even went to England, in order to place himself under his instruction. Some of his works are in the Churches at Grenada, for he was a Historical Painter; and there are many others in the hands of individuals both in Spain and England. *J. Athanasius Bocanegra* came nearest of any succeeding Painter to the style of Moya and Vandyke.

Murillo.

Barthélemy Esteban Murillo however is the chief glory of the School of Seville. This great artist, for such he is universally allowed to be, was born in the year 1618. With regard to his earlier studies it is worthy of remark, that he did not, as his predecessors had done in general, form himself upon the Italian model, but turned his attention to the Flemish Painters, or rather, as the last-mentioned artist had done, addicted himself to the principles of Vandyke. It is said, in fact, that it was from the visit of Moya to Seville, that he first gained an idea of what might truly be called excellence in Art; or, in other words, that line which he followed was the only one wherein were displayed those peculiarities which were congenial to his own natural ideas. Launching into the world without money or even friends, we see this young man sitting down and painting a few pieces of canvass, which he sold to a hawker to be carried out to the Indies, and with money thus raised he went to Madrid, and introduced himself to Velasquez. Velasquez was at this time a great man about the Court; but, far from being offended with his conduct, or feeling as a more vulgar mind might have done on such an occasion, he received him at once with kindness and even familiarity; taking care to lay open to his inspection all the choicest works in the Palace of the Escurial. In consequence of the advantages thus offered to him, we learn that Murillo staid there three years, and, from his studies and diligence so unremittingly pursued at the Capital, started at once as a finished Painter. This kind act of Velasquez was a moral lesson to Murillo, which he never suffered to be obliterated from his mind, and he, too, in his turn, when afterwards he had risen to eminence, always showed a generous readiness of disposition to every young artist who was presented to his notice. He it was, indeed, who first formed the project of establishing an Academy of design at Seville, which he finally succeeded in accomplishing, in spite of the great opposition with which he met. Murillo exhibited great talent, both in Historical composition and in the more homely figures of common life. As to style of design, he is one of those whom the Italians call a *naturalista*, that is, without any pretensions to Classical grace; but the truth and strength of character that pervade his Pictures, give him with the world in general a higher recommendation; to this he added a force and richness of colour equal to the best productions of his mighty prototype. The greatest and most perfect Painting by Murillo is said to be the *St. Antony of Padua*, which is placed in the Cathedral at Seville, and for which he received no less a sum than 10,000 rials from the Chapter. Some of his Pictures are to be met with in the Royal Palaces in Spain, and almost every collection of note throughout Europe will afford some example of this great master. It may be said that no artist, if we except Rubens, ever had the reputation of painting so many Pictures as Murillo.

pupils.

Of the pupils of Murillo whose Pictures are often confounded with his, it will be sufficient to mention the names of *Antolinez, Villa Vicencio, Tobar, Menesco, Osorio*, &c. *Sebastian Gomez* is, perhaps, still more successful in his imitations.

Another follower of the style of Vandyke and Rubens was *Nino de Guevara*, who also lived in the XVIIth century; if, indeed, it is fair to introduce any such person as a parallel to the name of Murillo. We may close our account of the School of Seville with the names of *P. Camprobin* and *J. Arellano*, Flower Painters; *Joseph Antolinez*, (scholar of Ricci,) a Painter of Landscape, and *Henri des las Marinas*, as his title imports, a Painter of Sea-pieces.

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cia.

Nicholas Factor (*le béat*,) the Painter of *Madonne*, is the first name on the catalogue, in point of time, at *Valencia;* he lived early in the XVIth century. Of still more note, in regard to the degree of skill which he attained, was the *Pere Nicholas Borras*, who filled the walls, cloisters, altars, &c. of the Convent of St. Jerome di Gaudie at Valencia with his Paintings. He seems to have been indebted for his greatest proficiency in the Art to his acquaintance with the celebrated *Vincent Joanes*, a person of whom it is our duty next to take notice. Joanes, who is the glory of the School of Valencia, was born in 1523. He studied in Italy for some time, according to the fashion of the day, and there he learned to imitate, and not unsuccessfully, the manner of Raffael; so much so that some have supposed him to have been his pupil; the date of his birth however renders this impossible. The piety of his feelings deserves to be recorded, as well as his skill; for the same fact is related of him as of Louis Vargas, namely, that before entering upon a sacred subject he invariably prepared himself for the task by taking the Sacrament. At the Palace at Madrid are six magnificent Pictures by Joanes, representing the *History of St. Stephen;* and many of his works are to be seen in the Churches at Madrid, Segovia, Valencia, &c. His manner of. Painting is not altogether free from restraint, but still there is so much of energy, such skill in foreshortening, and such a flow and fulness in his draperies, as to make ample amends for this fault, and banish the imputation of poverty or servility from his style: his colouring, as might be expected, savours much of the Roman School. He had a son, *Vincent Jean de Joanes*, who must not be confounded as a Painter with his father, to whom he was greatly inferior in talent.

h.

Matarana and *Yavarri* were also respectable Painters of Historical subjects at that day, and chiefly in fresco. There were, too, three Historical Painters at Valencia of the name of *Zarinena.*

The Venetian style and manner of Painting seems at all times to have had great attractions for the Spanish artists; but there are few, if any, amongst their number who were more successful in seizing its peculiarities than *Petro Orrente*, of Montalegre, in Murcia. His favourite master was Bassano, and it was after his fashion that he used to paint both Historical subjects and those of common life. Examples enough are to be met with at Toledo, Madrid, Cordova, Badajoz, Valencia, and in his native Country; those which gained him the most admiration are eight designs from the Book of *Genesis*, in the possession of the family of De Huertas: he lived in the latter part of the XVIth century. Contemporary with Orrente was the Augustan friar, *Leonardo*, a Painter of History, Portraits, and Battle pieces. He received a commission from the General of his Order to decorate with Paintings his Convent at Madrid; and he was employed also in many works at Toledo, Cordova, Valencia, &c.

Ribalta.

Francis Ribalta was born in 1551, and chancing during his state of pupilage to fall in love with the daughter of his master at Valencia, and being refused the honour of her hand, he betook himself to Rome; probably as much for a diversion of his thoughts, as for the purpose of making himself considerable by his talents. There he employed himself in copying the standard Pictures of Raffael, the Caracci, and more particularly those of Sebastian del Piombo; and at his return, so gratified was his master by the talent he displayed, and so satisfied that he would make his way in the world, that he freely gave him his daughter in marriage. His colouring is rude, but in Drawing and composition he is excelled by few; and so much are his Pictures esteemed at Valencia, that the citizens of that place very unwillingly part with any of his works. He painted also for many of the Churches at Madrid, Valencia, Segovia, &c. *Castaneda* and *Bausa* were his best scholars. His son, too, *Johan Ribalta*, equalled his father, though he exerted his talent in a different branch of the Art, confining himself almost wholly to Portrait Painting. *Hyacinthus Jerome de Espinosa* also is said to have been a pupil of Ribalta, born in 1600; he painted Sacred History in good style; but there are three other Painters of this name and family, who were also Historical Painters. *Stephen March*, or *March des Batailles*, so called from the usual subjects of his pencil, acquired great fame from the bustle and spirit of his designs, as well as from their colouring, which

His pupils.

S. March.

resembled that of the Venetian mode. He had a pupil, named *Sotomayor*, of considerable merit in the same line.

Mathieu Gilarte a Painter of History, was a pupil of one of the Ribalta School, who served to keep alive the memory of that great artist: his Pictures are in most of the Convents of Murcia, Toledo, and Madrid; he was born in 1648. We must not omit the name of *Augustus Gasal*, who was formed in the School of Carlo Maratta at Rome, and whose heavy manner he followed: his Paintings are to be found chiefly in the Convents and Churches of Valencia, where he died at the beginning of the XVIIIth century. *Don Vincent Victoria* (the Canon) was a scholar of the same, and many of his Pictures, both in Italy and in Spain, pass under the name of that master.

FRENCH SCHOOL.

The art of staining glass with a variety of permanent colours was, as we have before mentioned, the invention of a Frenchman, William of Marseilles; but except in works of this description, which, however beautiful in themselves, are of a totally distinct nature from the usual studies of a School of Painting, little or no progress appears to have been made in France before the day of Francis I. We find, indeed, the name of *Jean Cousin*, who was born at Soucy near Sens in 1462, the author of certain Treatises on Art, and a few samples of whose practical talents are preserved by the engraver. We have also the name of *F. Clouet* or *Janet*, a Portrait Painter, and, in the Historical department, those of Dubreuil and Freminet, who were flourishing towards the middle of the XVIth century. But with the reign of Francis I. was introduced a new and more brilliant æra of Art. That monarch commenced his patronage by inviting Italian artists of high reputation to reside at his Court, *Rosso*, *Nicolo del Abate*, and *Primaticcio;* their style was captivating, and became fashionable; and thus, through a rage for Italian study and Italian taste, was developed the latent germ of native genius in France. Vouet. The first Painter of eminence who was thus brought forward was *Simon Vouet*, the son of a Painter at Paris, born in the year 1582. He was fortunate enough to meet with the patronage of the French Ambassador to Turkey, by whom he was carried to Constantinople, and afterwards sent to Italy, where he remained upwards of fourteen years; and let it be observed, that, though a Frenchman, his talents were such as to acquire for him even in that great seminary of Painters no ignoble name: the Picture of *The Assumption*, for the Chapel of the Chapter of St. Peter's, is reckoned one of his best works: there are many others, however, which have become familiar to the Public by the hands of the engravers. His pupils. In the School of this artist were formed *Valentino*, *Le Brun*, *Le Sueur*, *Dufresnoy*, *Mignard*, *Testolin*, *La Hyre*, and many others, who in their day did honour to their Country. Jacques Blanchard. *Jacques Blanchard* was a contemporary of Vouet, but far inferior to him in originality and talent: he, nevertheless, gained a great reputation from his successful imitation of the Venetian style, his compositions abound with female forms, and he gained the name of the French Titian.

Nicolas Poussin. A still greater artist next appeared, namely, *Nicolas Poussin*, who was born at Andely in Normandy in 1595. The greatest part of his life was passed at Rome; and by his unceasing application, during his residence there, he formed for himself a more truly Classical and learned style than any other Painter upon record, scarcely excepting Raffael himself. Still, it was not a cold or tame and lifeless grace which his figures exhibited, but a full nervousness of expression, that showed the deepest knowledge not only of the external and anatomical movements, but also of the inward emotions of the human heart. We have in England, in the collection of the Marquess of Stafford, some of his most perfect pieces, namely, *The Seven Sacraments*: engravings of his other more celebrated pieces, such as *The Deluge*, *The Philistines smitten by the Plague*, *The death of Germanicus*, and *The discovery of Moses*, are in the hands of all amateurs, and give a better idea of his style than any words can express. N. Poussin had no actual scholars under his charge, but there are few Painters of France of his day who were not indebted to him for advice; and still fewer of any day who have not profited by his example: we may safely say, indeed, that his manner gave the turn and fashion in France to all the artists that came after him; in short, the Poussinesque style is as truly the characteristic of the French School as the Raffaelesque is of the Roman.

Stella. We may mention *Jacques Stella* of Lyons, a friend of Poussin, as one who closely and successfully imitated his manner of composition; he was patronised by Cardinal de Richelieu. Many of the first People of the Court seemed to have imbibed a taste for Art from the example set them by Francis I., and there was no want of patronage to a young artist who displayed at this period any symptoms of talent.

Perrier. *Francis Perrier*, a native of Burgundy, born in 1590, went to Italy, and placed himself for a while under Lanfranc; but his unfortunate instability of disposition became his ruin, and he painted but very few Pictures, being at this day known in the world chiefly as an engraver. F. Blanchard. *Francis Blanchard*, of Paris, is recorded as a Painter of History about this period, and a very respectable if not a great one. He too studied in Italy, and followed the manner chiefly of the Venetian School. To these we may add *Jean le Maire*, a Painter of perspectives, and *Jean Mosnier*, a glass Painter. They also went through their course of study in Italy; for it seems as if fashion had now made this journey an absolutely necessary part of almost every Painter's education.

The next person whom we shall mention is one who did honour to his foster Country, and who deserves to be remembered by all his countrymen for his talent; the traveller in Italy will recognise a very beautiful Painting from his hand, which has the honour of a place in the collection at the Vatican Palace. Valentino. His name is *Moise le Valentin*, or *Valentino*, as he was called more usually by the Italians; he was born at Coulomiers in 1600; it appears that he left the School of Vouet, at Paris, in order to study in Italy, where he became a great admirer of M. Caravaggio, and after his fashion painted his figures in a strong, forcible style upon a dark or rather black background. His *Concert*, *Judith with the head of Holofernes*, and some few other of his Pictures, are well-known.

Mola. *J. Bapt. Mola*, or *Mola da Francia*, for he too was a Frenchman born, was another of those who abandoned the School of Vouet for those of Italy: he may be remarked, however, as having adopted a style directly opposite to the last-named artist, becoming a follower of the graceful and soft Albano; many of his Pictures are, indeed, after passed under the name of that great master. *Jacques Callot*, also, whose little military pieces, the *Temptation of St. Anthony*, &c., are so universally admired, was of this day, and, like the others, studied in Italy. We might mention, too, *Ferdinand Elle*, who as a native of Malines rather belongs to the Flemish School, yet constantly resided at Paris, and is but little known elsewhere. He painted Portraits chiefly. He left a son behind him in the same line, usually known under the name of *Ferdinand the younger*.

Up to the time of which we now speak, the Painters in France seem generally to have exercised all the several branches of the Art of design; this appears evident upon considering the very various specimens sent by them as their contributions to the earlier exhibitions of the Royal Academy of Paris. Many difficulties, it seems, here, as in other Capitals, stood in the way, and much was to be done before this establishment was settled on a proper foundation. The name of the Academy, indeed, existed as early as the year 1648; but, notwithstanding, it is quite clear, that it was not till seven years afterwards, that letters patent were obtained for its formation under Louis XIV. In his reign it received great encouragement, its funds were large and numerous, and Chairs and Professorships, and honours of various sorts, were accorded to it. A most important addition was afterwards made to it, by the establishment of a second Royal Academy of France, in the seat of the Arts, at Rome itself; where young French artists, who were deserving of patronage, might be received and assisted in their studies. This plan was not finally accomplished until the year 1765. The Palazzo Medici on the Monte Pincio, having then been purchased for this purpose, is the present residence of the young Frenchmen during their period of study at Rome.

Sueur.

Le Sueur, one of the most zealous partisans of the Academy, and who uniformly supported its interests against those who were adverse to its formation, was born in the year 1617; and his name is commonly mentioned by the French writers with more than ordinary delight, as affording the best specimen of what pure, native French talent has been able to effect. It is true, indeed, that he never studied in Italy, but at the same time it is evident to the most casual observer of his works, that he must have formed himself chiefly by attention to the works of Italian Painters; and though there are few who have been provided with a greater stock of invention and natural feeling, yet, again, there are few who exhibit in their compositions such strong lineaments of imitative Classical study. His colouring is not forcible, but still possesses a certain degree of harmony, which soothes the eye of connoisseurs, and makes them forget his faults. Harmony, indeed, and milder affections of the soul seem alone to be natural to Le Sueur; but still he was sufficiently powerful to excite, by the manner of his design, a strong interest in the mind of the spectator, and may be fairly classed among the best of those whom a Roman would place at the head of the Transalpine School. He died at the age of thirty-four, but left even in this short life many works to attest his ability and skill; of these we may mention the *Life of St. Bruno*, *St. Paul preaching at Ephesus*, *The Martyrdom of St. Laurence*, *Our Saviour with Mary and Martha*, *Our Saviour carried to the Sepulchre*, and *Alexander receiving the cup from the hands of his Physicians;* most of which have been made known to the public by the labour of the engraver. *Nicolas Colombell*, of Sotteville, was his only scholar who attained any great name.

Claude.

The name of *Claude Lorrain* has of late years been inserted in the catalogue of French Painters, but they have little claim to this great man, since his native province was not yet annexed to France: it does not appear indeed that he ever set his foot within the limits of the French Monarchy, and his style was formed where his life was almost wholly passed, namely, at Rome.

Dufresnoy.

The name of *Dufresnoy* is known rather from his Poem on the *Art of Painting*, than from the specimens of his pencil, and therefore may be passed over in this brief History of the Art; but the next name occurring on the catalogue, is that of one of the most distinguished French artists, namely, *Sebastian Bourdon*.

Bourdon.

He was one of those instances of precocious talent whose life, contrary to vulgar prejudices, was prolonged so as to enable him to justify the promise of his early years: he was born at Montpellier in 1616, and at the age of fourteen designed and executed in good style, as it is said, a *plafond* in the house of a gentleman near Bourdeaux. In a later period of his life, after his return from Italy, we find him equally happy in his composition in all the three chief branches of the Art, in History, Landscape, and Portrait; while it may fairly be said, that his imitations of Poussin, Caracci, and Sacchi, are of a nature to deceive the eye of even an experienced connoisseur. *Jacob carrying away the idols of Laban*, *The Virgin and Child*, *The Seven Labours of Piety*, and some others, have been engraved; and a beautiful Landscape, given by the late Sir G. Beaumont to the National Gallery in London, is familiar to the public.

Le Brun.

Owing to a reputation which was enhanced beyond its due merit, by the favour and partiality of the Court of France, there are few Painters of that Country whose names have a more extensive reputation than that of *Le Brun*. He had some talent, certainly; but he will be quoted always by the judicious connoisseur, as affording a sample of the worst style of Historical Painting that ever forced itself upon the public notice; *Le Brun peint a nos yeux le fier et le terrible*, says the Poet, nor can we characterise his style better than by these two words: and yet it is not that sort of fierceness and terror which interests us in looking at a Picture, it is one continual bustle, that distracts the attention, and offers no rallying point for the Imagination or the feelings. Repose is a quality utterly banished from his works; and though he represents, in some of his Pictures, the Passions of the Soul, and even wrote a Treatise upon the subject, it is only in their vulgar and most staring forms that they are ever depicted by him on the canvass. No one is farther removed from the Poetic dignity of the Art, which alone enables it to interest and ennoble the mind. He gives the most perfect sample of that deficiency of sedateness and grandeur of style, which the Classical Winckelmann describes, by borrowing from the Ancients the term *parenthyrsis*.

His pupils.

Verdier, *Houasse*, and *Audran*, were the scholars and assistants of Le Brun, whose style they imitated with but too much servility: indeed, it may be said, that in consequence of the splendour of a name honoured as his was by Court favour, his style not only became the fashion of his own day, but has stamped a character on the French School, which it retains in great measure even to this time; and in spite of the ingenuity of modern declamation and the judgment developed by modern connoisseurs, the annual exhibitions at the Louvre savour more strongly of the fierceness and audacity of Le Brun, than of the chaste energy of Poussin.

Mignard.

Peter Mignard and *Nicolas Mignard*, two brothers, born at Troyes, and both distinguished Painters of Portrait and History, flourished during the earlier part of the XVIIth century. Peter, however, who studied for many years in Italy, was the more celebrated of the two: he succeeded Le Brun in his place of Chief Painter to the King of France, and some splendid specimens of his talent are still to be seen in the Royal Palace at Versailles; where the connoisseur will observe, that if he fail in force and dignity of expression, there is yet a softness and harmony of composition, and freshness of colouring, demanding our admiration.

Lenains.

The two *Lenains*, *Louis* and *Antony*, were excellent Portrait Painters, and they have left behind them also some groups of figures, designed in a picturesque style, which are remarkable for their freshness of colouring, and happy facility of expression: they died about 1648; little else is known of their history.

Philip de Champagne

Philip de Champagne belongs, by birth at least, to the Flemish School, but he passed the greater part of his life at Paris; and his Portraits, or compositions containing few figures, possess great merit.

Bourguignon.

Jacques Courtois or *Bourguignon*, (as he is usually called,) is well known from his spirited Battle pieces; he passed the best of his days, and painted his best Pictures, in Italy. He left behind him a successful imitator,

Parrocel.

in his countryman, *Joseph Parrocel*, who, upon his return from his studies in Italy, obtained employment at the Court under the reign of Louis XIV.; this was at the time, too, that *Vandermeulen* had long enjoyed the chief favours of his Majesty, and was regularly retained by him to detail with his pencil the military glories of the day.

Coypel.

A. Coypel was one of the best Historical Painters of Paris towards the end of the XVIIth century; in his Pictures we first trace the appearance of French faces and French manners in the personages represented on his canvass; a fault which afterwards became very common amongst the secondary Painters of the French school: Athaliah, Jephthah, Solomon, Susannah, Venus, &c., are all so many French men and French women in disguise, as may be seen in the engravings after his works. There were four artists, however, of some note belonging to the family of *Coypel;* nor were the stocks of *Hallé*, *Boulogne*, and *Detroit*, much less prolific in Painters, though their fame is not very much extended beyond the limits of France.

De Lafosse.

De Lafosse deserves our notice for the neatness of his colouring; some of his chief works were his Paintings at the Palaces of Versailles and the Trianon, and he was also much employed in England by the family of the Duke of Montague. His nephew, *Ant. Pesne*, was a respectable Portrait Painter, who established himself in the service of the King of Prussia at Berlin, where he finished his days.

Pesne

Jouvenet.

Jean Jouvenet is celebrated for his Picture of the *Descent from the Cross*, which is said to be one of the best compositions of the French School: many other of his works have been engraved, and it must be confessed, that he is not devoid of originality or greatness of manner: he died in 1717.

Sophie Cheron.

At the same time flourished *Sophie Cheron*, who attained a high and deserved reputation in her day: her style of design was tasteful, and her colouring excellent: it was her brother, *Louis Cheron*, who was driven to England at the time of the Revocation of the Edict of Nantes; his works are often to be met with, and never fail to attract our attention by their very Classical and pure style of design: we have many of his designs in one of the large-sized editions of the Bible used in Parish Churches.

Louis Cheron.

Nicolas de Largillière.

Another French artist, who found employment in England at that time, was *Nicolas de Largillière*, who even at the early age of eighteen surprised the King, Charles II., by the vigour and freedom of his pencil: he did not live in England, however, but went back to his native Country, where he attained the favour and applause of his brother Academicians, though he cannot be said to have been honoured by the patronage of the Court.

Rigaud

Hyacinthe Rigaud, a native of Perpignan, gained great admiration at Paris, for the beauty of his Portraits. Rigaud is the Vandyke of the French School, as *J. B. Monnoyer* is their Van Huysum: there are, perhaps, few men who have attained greater reputation in this line: he was generally assisted in his labours by his relative and scholar, *De Fontency*, who perhaps painted with more truth and fidelity, if with less of Poetical spirit than his master.

Monnoyer.

De Fonten

Watteau.

The Pictures of *Watteau*, whose name next occurs in the list, are *bouquet*-like in point of the exquisite effect of their colouring: though, perhaps, they enchant us still more by the lively comic grace of his figures, and the spirit of his design.

Le Pautre, *La Fage*, *Le Maire*, *Le Moine*, *Cazes*, *Raoux*, *Nanteuil*, *L. Ferdinand*, &c., as Painters of Portrait or History; *Petitot*, as an Enamel Painter, *J. Forest*, *J. Rousseau*, his pupil, *Meusnier*, and *P. Patel*, as Landscape Painters, and many other artists of a secondary rank, were flourishing about the end of the XVIIth century, and beginning of the XVIIIth, at a time when the Court had shown a most indulgent spirit of patronage for the Art, and almost every great officer of State, every farmer-general of the finances, every prelate of the church, or even every banker of eminence, became anxious to signalize his wealth or his taste by becoming a purchaser of Pictures, and an amateur of the *beaux arts*.

Some of the best works executed at this time at Paris were the architectural pieces of *Servandoni*, a native of Florence, and pupil of P. Panini: and of those of the native Painters, we may mention the *Brazen Serpent* by *P. Subleyras*, a Picture which displays talent of a high order. Some other valuable Paintings by this artist are now to be seen in the Louvre.

Subley

De Tro

Of merit scarcely inferior are the Historical compositions of *Fr. de Troy;* his *Salmacis and Hermaphroditus*, *Solomon and the Queen of Sheba*, &c. Those of *Restout*, also, (in spite of an almost tedious mannerism, displaying itself in a certain precision and angularity of design,) are pictures of merit.

Restou

Bouch

Fr. Boucher, a scholar of Le Moine, gained also a great name at Paris; and there are few artists whose works have been more largely made known than his have been by the assiduity of the engravers; but his reputation was chiefly obtained by the facility with which he represented the graces of the female sex, and by scenes in which their unveiled charms might be exhibited to advantage; he sought, in fact, to allure purchasers by exciting their passions, because he was unable to produce any admiration by his taste or skill. He had many scholars and followers who were successful in his style, if success it may be called,—for it was only success in finding a vent for their productions,—these were *Bourdouin*, *Mettai*, *Des Hayes*, *Fragonard*, and *Juliard*, who was also a tolerable Landscape Painter, and *Le Prince*, a Painter of Pastoral pieces, &c.

The names, however, which reflect the highest honour on the French School, in the middle of the XVIIIth century, are those of *Vernet*, *Chardin*, *Greuze*, and *Latour*.

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The Sea pieces of *Vernet*, for the boldness of his design, and the strength and force of his effect, are beyond all praise; but he introduced, it must be confessed, a certain air of artificial peculiarity not only into the attitudes of all his figures, but even into his tone of colouring. He may truly be called a complete French Painter.

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Chardin painted Portraits, animals, fruits, figures, &c., all with the same true spirit of execution, happiness of touch, and fidelity to Nature. *Greuze* succeeded chiefly in his fortunate power of seizing and portraying the more common and familiar emotions of the soul; his subjects are not heroes or demigods, but are usually taken from the middling classes of common life, and there are few people that will not feel a sympathy in the scenes which he represents: he stands alone in the French School in this walk of Art. *Latour* excelled only in the use of the crayon, but by his spirit and truth of manner he gained a well deserved name. Louis XV., the Dauphin, Voltaire, and many other persons of rank and fame, were painted by his hand.

nloo

Under the name of *Vanloo* we have Charles, the son of a Painter at Nice, born in 1705, and who had completed his studies under Benedetto Luti at Rome. At Paris he soon excited public attention, received the honourable appointment of chief Painter to the King, and was decorated with the Order of St. Michel. *The flaying of Marsyas*, *The chaste Susannah*, *The Three Graces*, &c., are among those of his works which are most known, and best deserve to be so. He must be regarded, however, as a man shining in consequence of the weakness of his competitors and contemporaries in the profession, rather than by the vigour and force of his own ability. His scholars are *Lagrenè*, (the elder,) *Doyen*, *Julien*, *Olivier*, &c. His brother, *Charles Philip Vanloo*, and his son, *Louis Michel Vanloo*, both were Painters of Portrait and History: but the chief glory of the family is derived from *J. B. Vanloo*, of Aix, born in 1684, but who of course does not belong to this School, at least if we regard the locality of his birth.

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We may close the list of the School of France with the names of *Nicolas Laneret*, a successful Painter of familiar scenes, and a pupil of Watteau; *J. Pillemont*, a tolerable Painter of Landscape; *Robert*, a Painter of architectural ruins and picturesque compositions of that nature; and, though last not least, *David*. The works of the last are full of the restlessness of the style of Le Brun, and are familiar to all visitors at Paris of the present day. Yet here it is but fair to say, there appears to be more talent in the Painters now living, and more promise of honour to the French School in the Historical line, at least, than the latter part of this sketch would have led us to infer. They must be allowed to have succeeded in some respects beyond their contemporaries, either in England or yet in Italy. If we were to hazard a critique upon them, we should say, that the line they have adopted savours too much of an artificial imitation of the antique on the one side, and of theatrical gesture on the other; and they certainly never succeed in entirely divesting themselves of a certain Frenchified air, as to the attitudes of their figures, which stamps them, in spite of their real merit, with incontrovertible marks as the most decided mannerists of the Age.

ENGLISH SCHOOL.

The most diligent researches of the Historian afford but few notices of native British artists, or, at least, of such as deserve that name, previous to the XVIIIth century: and certainly there are none who can, as to their style, boast of a character of their own, or who possess such merit as to enable us to speak of them as forming a School of Painters. From the earliest times it seems to have been the custom, both with the Court and with the Prelacy, to send for foreigners either from Italy or from the Low Countries, for the execution of any important pictorial decoration. Thus were introduced P. Cavallini, in the reign of Henry III., and in after-times John of Mabeuse, H. Holbein, Lucas de Heere, Marc Willems, Sir A. More, C. Ketel, F. Zucchero, Gentileschi, Honthorst, C. Jansen, Rubens, Vandyke, Vandevelde, Sir P. Lely, and Sir Godfrey Kneller; and a host of other foreigners, with whom it was difficult for the homeliness of native skill to maintain a struggle. The very names of the workmen and inferior artists employed in the more mechanical part of the works intrusted to the Painters just mentioned, appear in early times to have been generally foreign, and the Art seems to have been regarded as a mystery of a rather occult nature. We must suppose, however, that the example afforded by the labours of such illustrious strangers, and the extreme admiration excited by their works, would have some effect in exciting a spirit of emulation, or, at least, of imitation, amongst our Countrymen; and to this circumstance we are indebted for the formation of those few British artists who, though of an inferior description, are all that this Country can boast of in days of yore. Such was *Master Walter*, employed by Henry III. upon certain Paintings in the Palace at Westminster. Such was *John Thornton*, of Coventry, who painted the east window in York Cathedral, during the reign of Henry VI. Such were *Andrew Wright* and *John Brown*, Serjeant Painters, as they were called, and Members of a chartered Society, which was formed in the reign of Henry VIII. Such, in the succeeding reign, was *John Bossam*, of whom, however, we know nothing more than is to be gleaned from the commendatory remarks of a contemporary artist. Such, too, was *Hilliard*, in the reign of Elizabeth, who has some little claim to our notice, as being one of the masters of Oliver.

Oliver.

Isaac Oliver is the first British artist on record of whom we can safely speak with any degree of commendation; and whencesoever his family was originally derived, for this is a disputed matter, he, at least, was certainly born on our soil. His province was Portrait Painting in miniature, many specimens of which are now preserved. Those of his works which are most known, are a head, supposed to be that of *Mary Queen of Scots*, and others of *Queen Elizabeth*, *Ben Jonson*, &c. He died in 1617, leaving a son, *Peter Oliver*, who imitated his father's style with much success.

Thomas and *John Bettes* also were living in this reign, and painted Portraits with much truth and fidelity of manner,—their fashion being evidently built upon the taste introduced by Zucchero, or some other Italian. *Lyne, Peake, Arnold, William* and *Francis Segar*, and *Peter Cole*, also are chronicled as Painters of renown in this reign; but, as to their deserts, they may be passed over. We find that the munificence of Charles I. and his Court, called forth some latent sparks of genius from amongst our countrymen, but even these artists were formed after the examples and precepts of the foreigners who were then so largely employed in England. The decoration of the Banqueting-house at Whitehall, the purchase of the Pictures of the Duke of Montrose, and the encouragement and patronage given by the Court to such men as Rubens and Vandyke, inspired a new feeling into the People of England towards the Arts of design, and left an impression the effects of which were visible during the succeeding Age.

Dobson.

William Dobson was born in 1610: he came to London while young, and some of his Pictures, exhibited for sale, having by chance attracted the attention of Vandyke, that great artist had the generosity to recommend him to the favour of King Charles. From that day his fortune was secured, for he had merit enough to ensure his success, as soon as an occasion of displaying his talent was offered him. He gave so much satisfaction to his Majesty, that he finally succeeded, at the death of Vandyke, to the place of Serjeant Painter. He painted both Portrait and History; and his *General Monk*, &c., at Chatsworth, and *The Beheading of St. John*, at Wilton, may be mentioned here as being among the best specimens of his skill in these two departments of Art: as to merit, he may be classed (and it is no small honour) among the most successful imitators of Vandyke.

Jameson.

George Jameson was a pupil of Rubens, whose manner he chiefly followed: most of his works are to be found in the seats of his Countrymen in Scotland, and, if not quite equal in beauty to the pieces of the last-named artist, they are of a degree of merit by no means to be despised.

A. Cooper.

Hoskins.

Alexander Cooper, an excellent drawing by whom, representing *Acteon and Diana*, is preserved in the collection of Pictures at Burleigh, was also an eminent native artist who flourished in this reign, as likewise did his uncle, *John Hoskins*, a Portrait Painter.

After these we may mention *Robert Walker*, a Portrait Painter, who was much noticed and patronised by Cromwell, during his usurpation. The Protector had his Portrait taken both by *Walker*, and another Painter of the name of *Edward Mascall;* as well as by *Sir P. Lely*, *Samuel Cooper*, and *Gibson*, the Dwarf.

Fuller.

Isaac Fuller's inimitable Picture of himself, when in a state of intoxication, will be called to mind by every one who has visited the Picture Gallery at Oxford. He showed more talent as a Painter of Portrait than of History; nevertheless, there is a Historical composition from his hand, executed in *chiaro-oscuro*, at the altar of Wadham Chapel in the same University, which shows no mean talent, even in that arduous and difficult province of Art.

Streator.

We must have recourse to the same University, for illustration of the manner of the next Painter on record, namely, *Isaac Streator*, Serjeant Painter to his Majesty, who designed the pictured ceiling of the Sheldonian Theatre: it is a remarkable fact, that these men, who were two of the chief Painters of the reign of Charles II., made their early studies not in Italy, as was the general fashion, but in France,—the one placing himself under Perrier, the other under Du Moulin. We may here also mention the name of *Henry Anderton*, though there is not much more to be said of him, except that he was a pupil of Streator, and obtained favour at the Court.

Lely.

His pupils.

Sir P. Lely became in the latter part of the XVIIth century the great artist of the day, and though we cannot class him in a catalogue of British artists, (for he was a native of Westphalia,) he formed many scholars among the People with whom he settled, and influenced more, perhaps, than any other man the progress of the Art in Great Britain. Of these *John Greenhill*, of Salisbury, may be named as the best: specimens of his manner may be seen in any large collection of engravings; also *Thomas Sadler*, a favourite of Cromwell, who, upon the Restoration, was in the latter part of his life obliged to have recourse to the profession of a Painter for his subsistence; nor did he discredit the Art which thus adopted him. *Davenport* was another of his scholars, who, however, died young; another was *John Dixon*, a Painter in miniature and crayons. An imitator, too, if not a scholar, was *Mrs. Beale*, who painted several Portraits of distinguished personages of the Age, some of which are in the possession of Lord Ilchester, at Melburn. *Richard Gibson*, the Dwarf, was an imitator also of Lely, being almost wholly formed upon his model.

S. Cooper

Of those who were formed on a more liberal system than the trammels which Court fashion and favour had imposed on the Art, we may quote the names of *Michael Wright*, a Scotchman, who was employed to paint the Judges in Guildhall; *Henry Cooke*, sometime a scholar of Salvator Rosa in Italy, the Painter of an equestrian Picture of Charles II., at Chelsea College; and *John Riley*, who came into notice at the death of Lely, to whom he can scarcely be said to be inferior. Both Charles II. and James II. sat to him for their Portraits; but perhaps his best Picture, after all, is that of Lord Keeper North, at Wroxton Abbey. Far beyond these, however, in fame, is the name of *Samuel* Cooper, who is well described by H. Walpole, as "*owing great* part of his merit to the works of Vandyke, and yet an original genius, as he was the first who gave the strength and freedom of oil to Miniature Painting." He lived a long time in France and Holland, but died in London in the year 1672, and was buried at St. Pancras Church: he is, perhaps, the first instance of an English Artist who met with employment and favour at a foreign Court, as he is reported to have done at that of Paris.

Kneller.

Jerva

Richard

High

We now come to the opening of the XVIIIth century. The days of *Sir Godfrey Kneller* had passed away, but yet long cylinder waists, and balloon gowns, and branching caps, and five-curled perriwigs, remained; and the artist was incumbered with difficulties of dress that seemed almost insurmountable to a lover of the picturesque. *Jervas*, who had studied awhile under this artist, seems, as we learn from Pope, to have stood highest in the public estimation in the reign of George I.; he deserves, however, but little credit: *Richardson*, at least as far as painting a head may qualify him, was a better artist; and we may learn from his writings, that his ideas had attained a yet greater perfection than his hand was able practically to display. *Jos. Highmore*, another pupil of Kneller, is an artist now better known to the Public by the productions of the engravers, than from the works of his own hand.

r J. ornhill. *Sir James Thornhill* belongs also to this reign, whose designs, illustrative of the Life of St. Paul, for the interior of the cupola of the Cathedral dedicated to that Saint in London, and whose Paintings in the Hall at Greenwich Hospital, have made his style familiar to our recollections. If he does not attain any very high degree of merit, at least we feel a satisfaction in seeing that a native artist, who was of consequence enough to be selected for the execution of these public works, obtained that favour in the public eye, which had lately been lavished on foreigners alone. *R. Brown* was his pupil and assistant, and some original Pictures by his hand are to be seen in the Churches of St. Botolph Aldgate, St. Andrew's Holborn, and the Chapel in Bedford-row. *Ch. Collins* and *Luke Cradock*, also Britons born, deserve mention at this period for their pictures of still life, birds, game, &c.

ooton. About the middle of this century flourished *John Wooton*, a landscape painter, who had formed a very creditable style on the principles of Claude and Poussin; many of his pieces of this sort, as well as hunting and racing pieces, are to be seen in the country-seats of our nobility, at Badminster, and elsewhere. He died in the year 1761. *George Lambert* was afterwards a follower of his style and manner, and, perhaps, as good an artist as he.

dson. *Thomas Hudson* was a very respectable painter of velvet coats, and tied-wigs, and satin waistcoats; besides which it must be said, that he now and then struck out a head with considerable truth and fidelity to Nature. Whatever were his merits, however, he certainly took the lead of the profession in England, until the day that his great pupil, Reynolds, arose, to teach the nation a new lesson on the Art.

yman. We must not, however, suppose these times were otherwise devoid of that which may more immediately deserve the name of native talent. *Frank Hayman*, whose designs for Newton's Milton are well known to every one, certainly was an artist of considerable ability: we might add, indeed, that his paintings for the Gardens at Vauxhall are examples such as will serve to prove that want of invention is not among the deficiencies of our national character. *Thomas Worlidge*, too, has left behind him some good Portraits both in miniature and in oil; and his etchings and imitations of the style of Rembrandt are deservedly held in the highest esteem, bearing a high price when offered for sale even at the present day. lidge.

It is time however to mention those illustrious names who are the boast of our Country in the XVIIIth century, and which give us the only title to the name of a British School of Art, namely, *Hogarth*, *Reynolds*, *Gainsborough*, and *Wilson*.

rth. *William Hogarth* was the son of a tradesman in the parish of St. Bartholomew, in London; he was apprenticed by his father to an eminent silversmith, but urged by that ardent passion for Painting, the early effects of which are so often related by the Biographers of artists, he devoted himself to this pursuit as soon as the term of his apprenticeship to the trade had expired. He soon showed talents, and found employment, though at first only among the booksellers, who engaged him in making various plates of illustration, and works of that nature; of this description, indeed, was the first work which gained him any great share of public approbation, namely, the Designs for Hudibras, which are found accompanying the common duodecimo edition, published about the year 1720. The Painting of *Modern Midnight Conversation* was an effort of a higher nature, and one which at once displayed the greatness of the talent of Hogarth; and at the time when his next work, *The Harlot's Progress*, was produced, subscriptions were poured in most eagerly from all persons and from all quarters, every one seeming anxious to see it engraved. This engraving was done by the hand of Hogarth himself; but so great was the demand for the plates, and so extensive their sale, that pirated prints forged by other hands were quickly brought forth, and the inventor was cheated of nearly half his reward. So highly was the subject in favour with the public, that it was not long before it made its appearance on the stage as a melodrame, which was performed many nights with infinite applause; the enthusiasm which it excited, redeemed England from any accusations of indifference to Art, or, what is still worse, fastidiousness to the produce of our own native realms. We need not follow Hogarth through the long and successful series of publications that ensued: every Picture which he conceived, showed that he, and he alone, of all that had yet been known, possessed the power of exhibiting the true spirit of Comedy upon the canvass; and hence he became remarkable, as being in some sort the author of a new department in the Art. Perhaps it would be more just to describe his line as the serio-comic, and in that phrase we shall see enough of distinction to prevent us from confounding his style with that of the humorous Painters of Holland or Flanders. His Portraits are not very common; but those which are now to be met with, for instance some at the Foundling Hospital, possess apparently a truth of character that has rarely been surpassed; they are also extremely well painted, in regard to the more mechanical part of the Art. In this respect, indeed, they possess higher merit, and are better executed, and their colouring is more chaste than that of some of his other compositions. In his *Danae with the Shower of Gold*, and the *Sigismunda*, he afforded us a very strong and forcible illustration of the truth of the old adage, *Naturam expellas furcâ tamen usque recurrit*: either of the figures would have done credit to *The Harlot's Progress* or any other of his Pictures of that description; but neither the one or the other were at all in accordance with the grace of the Mythological story, or the ideas of gallantry which attach to Romance. Hogarth's *Analysis of Beauty* is an erroneous visionary Treatise, yet by no means devoid of merit; it contains, indeed, much matter that may be read with advantage. In private life Hogarth was an eccentric character, and showed, that if he thoroughly understood the foibles of the world in general, he had but too little bestowed his leisure in contemplating his own. He died in the year 1764.

Sir Joshua Reynolds was of a character directly opposite to the last-named artist; he had, like him, indeed, talent enough to excite the attention of the Public, and, in fact, to create a taste and relish amongst his Countrymen for those graces of form and character which are so peculiar to his pencil. But these were of a directly opposite nature to the fancy of Hogarth. His style as a Painter may be said to be chiefly founded on the study of Corregio, assisted and enriched by gleaning whatever suited his purpose from the modern Reynolds.

Italian and French schools. In Portrait Painting he stands unrivalled, notwithstanding the very absurd and unpicturesque fashions and dresses which prevailed in his time, and which it required no small skill and ability to handle in a way fitted for the canvass. In his larger works, and generally in his attempts at Historical composition, we have to lament a want of skill in Drawing, which very materially detracts from the pleasure afforded by his Pictures: but there is still a grace of form, and a truth of character, together with a chaste and harmonious glow of colouring in all that he does, which forbids us to dwell too much on those faults which the keenness of criticism might detect. The collection of his works in mezzotinto plates, now in course of publication by his namesake Reynolds, is a noble monument of native British talent and taste, creditable to the engraver as well as the painter himself; and be it remembered, that the very distinguished Portrait Painters of the present day, who raise our name so far above that of any other contemporary School in Europe, as to that branch of the Art, may chiefly be considered as followers of this great man.

Wilson.

Richard Wilson was a native of Wales, who was happily diverted from the profession of Portrait Painting, in which he had originally embarked, to the study of Landscape; and this change he is said to have been induced to make in consequence of the commendations which he received from Zuccarelli. The style he adopted was, indeed, an improvement upon the manner of that master; his principles and his objects are the same, but they are simplified as to light and shade, and even to colour, in a way to which the foreign artist was wholly a stranger; and hence arises that majesty in point of composition, that depth of tone and colour, and that sublime breadth of effect, which characterise the best Pictures of Wilson. In his journey to Italy, his Pictures excited the genuine admiration of the French artist, Vernet, who was at that time much in fashion at Rome: and this first made the English People sensible of the merits of one whom, perhaps, they overlooked, as being their Countryman. It was on the Italian soil alone that Wilson found scenery congenial to his taste, and having so found it, he soon discovered the way to perfect himself as an artist. The collection of his sketches, in the possession of the Earl of Dartmouth, and of Mr. Bowles, of North Aston, display certainly some of the finest samples of Classical elegance in Landscape, that ever were produced by any artist of this Country. Fortunately, however, we need not have recourse to private portfolios to enable us to scan his merits; many of his best pictures have been immortalized by the engravings of Woollet, and other samples of his noble genius are preserved in our National Gallery, by the generosity of his munificent friend and scholar, the late Sir George Beaumont.

Gainsborough.

Gainsborough excelled both as a Portrait Painter and as a Painter of Landscape: there are few better native Pictures than that of the *Misses Linley*, painted by this master at Knoll. But it is by his skill in the other line, that his great and deserved reputation was chiefly acquired. His works have, indeed, a peculiar charm in our eyes; because their beauties are purely of home growth, unadorned by Classical ideas of form, and stripped of all those pleasing but false associations, which so often attract our gaze in the compositions of other Painters; he pleases, because he presents us with the true features of our own verdant Landscape; he shows the swelling forms of our hills and dales, and exhibits faithfully and accurately the rusticity of our island habits; but to all these he has lent their own peculiar beauty and touch. He has given them that interest which truth of character never fails to impart, and by his possession of skill as an artist, he has blended them into one rich and harmonious whole. It was, indeed, remarkable how much Gainsborough rose in general estimation during the exhibition of the works of British Artists, some few years ago, at the Gallery in Pall Mall, and that, too, even in opposition to the more learned style, and to the acknowledged talent of Wilson. But the truth was, that the touches of his pencil came home to every man's own bosom, and we felt that we had, in every sense of the word, a British Painter.

Wright. Webber. Mortimer.

Of other artists in this line we may mention *Wright*, of Derby, as one of very high power and attainments; his moonlight and firelight effect are inimitable in their way; though his Pictures are not much known, for they are not often to be met with except in the country-seats of gentlemen in his own part of the country. *Webber*, too, demands our notice; the artist who accompanied Captain Cook on his third voyage to the South Seas, and who has depicted the features of the Austral islands and their inhabitants with admirable fidelity. He died in 1793. *Mortimer*, of whom it is no small praise to say that he was a successful imitator of Salvator Rosa, is also an artist of whom his countrymen may be proud; his pictures are ill coloured and heavy, but his design, such as is seen in the common engravings, is full of energy and vigour of soul.

Wheatley. Morland.

Francis Wheatley may be considered as one of our most respectable artists, both in the department of Landscape and Portrait. We cannot close without allusion to the name of *George Morland*, one who, in even the low and groveling line which he pursued, yet showed, by his manner of treating his subject, that abundance of picturesque beauty may be found, by a sagacious eye, in every object, however unpromising it be commonly considered. His character, that is, his character in a moral sense, is said to have been spoiled, and his education stinted, through the avariciousness of his father; and so far he deserves our pity, not blame: his mind felt its own unfitness for that rank in society to which his talents entitled him, and which his friends and admirers gladly invited him to assume; from this he was driven to low and profligate habits, and ultimately conducted to scenes of dishonesty, in which there seems to be some suspicion that he was but too deeply implicated. Under such circumstances, (for no man betrays his moral character more than a Painter,) it must be supposed some pieces betray the idleness and carelessness of his habits; nevertheless, a well-finished Picture of Morland, and such many of his earlier works may be called, is a jewel in the cabinet of the connoisseur. He died in 1804.

Hamilton.

Hamilton is as well known, or perhaps better known, by his works at Rome, than in England or his native country; they are chiefly Historical compositions, filled with tall elegant figures, employed in the gentlemanly-heroic style. He died in 1801.

Historical Painting, however, is the great walk of Art, and there are few, in modern days, who may be considered as having attained even a commendable degree of advancement in their endeavours to abide this much neglected, but universally acknowledged, test of genius and of highest intellectual merit. If we except some ephemeral productions of the Panorama, exhibiting, not unfrequently, considerable power, and inducing us to regret the short period of existence that has been allotted them; the only efforts which we may consider as having been made on any large scale,—the only *opere di machina*—are the Pictures of Barry, for the Society of Arts in the Adelphi. If, in point of colour, they neither equal the richness of the Middle Age of Italy, nor the severity of the earlier Italian Schools, they exhibit a grace of form, and, in some instances, a degree of energy, not unworthy the followers of Raffaelle. They well deserve the public attention. The works of Barry's pencil, like the eloquence of his great Countryman and early patron Edmund Burke, betoken splendid ability and no ordinary daring; and he seems to have been incited to most patriotic enthusiasm by a taunting assertion of his contemporary Winckelmann, that "the English are incapable of any great excellence in Art, from their natural deficiency of genius, and the unfavourable temperature of their climate."[*]

rry.

After an absence of four years in Italy, spent in the usual course of Academic study, Barry must have hailed at his return to England, in 1770, the establishment of the Royal Academy, founded in the preceding year. His labours, both as an author[†] and a Painter, were incessantly directed towards the refutation of Winckelmann's severe aspersion. He advised a similar plan to that adopted of late years in the Academy, of employing the students, in addition to a course of drawing and study from the antique and from the life, to make copies under the eye of their Professor from Paintings of established merit. By this practice, they not only acquaint themselves with the *matériel*, or vehicle of their Art, but they also form a profitable acquaintance with the faults as well as excellencies of those masters, whose authority, indiscriminately followed, might mislead; and whose fascination of colouring might otherwise, not unfrequently, ensnare the youthful artist into palliation, or even imitation of glaring errors.

It was to be lamented, for his own sake, that the violence of Barry's temper hurried him into those contentions with his co-academicians, which impeded his projects, ruined his fortune, and seem, towards the close of life, to have impaired his reason. And yet, for the sake of his professional fame, perhaps his liability to excitement is to be considered fortunate. Had his personal character been less ardent, his pencil might have been less happy.

It has been doubted whether West, who, in 1791, succeeded Sir Joshua Reynolds in the Presidency of the above-named Royal foundation, should be numbered among the English School. He was a native of Pensylvania. But he was one of the first members and founders of the Academy in England, over which he afterwards presided. Placed over English artists, he must be looked upon as having influenced, in proportion to the general respect for his undoubted talents, the progress of the Art of Painting in this Country. His was a learned style, formed, like that of Reynolds, Wilson, Barry, and Fuseli, after consummate study abroad of the sublime fathers in Art. His smaller and earlier Pictures are superior to his later and larger productions, in which his forms, though not deficient in simplicity or in correctness, generally want intellectual elevation. Opie, still less refined, is more vigorous. Opie, in design, betrayed the disadvantage of having wanted Academic initiation; but his pencil, true to individual Nature, was bold and unaffectedly impressive, and his colour excellent.

Opie.

Fuseli.

Of Fuseli we may observe, that he united much of sound classical learning, with much also of eccentricity and love of mysticism. He was born at Zurich about the year 1739. The lavish praise of Reynolds on some of this artist's early drawings, turned him from his intention of entering Holy Orders. He was the fellow-student and friend of Lavater, a translator and correspondent of Winckelmann, and himself an author of *Reflections*, which appeared in 1765, *on the Painting and Sculpture of the Greeks*. His Lectures as Professor in the Royal Academy excited general attention, and, like those of Barry, Opie, and others, his predecessors in the Professorial chair, have been published. Towards Barry he entertained a mortal and, perhaps, national antipathy, which in his edition (1810) of Pilkington's *Dictionary of Painters* has betrayed him into most uncandid bitterness. Fuseli, however, was behind none of his contemporaries in zeal for the promotion of his Art. He continued to paint till within a week of his death, in April, 1825. He is generally believed to have suggested to Alderman Boydell the idea of a Gallery to illustrate scenes from Shakspeare.[*] To this collection he contributed eight of his best Pictures; and afterwards being advanced, in 1790, to the rank of Academician, he painted a series of forty-seven subjects from Milton, exhibited under the title of the Milton Gallery.

The mind of Fuseli was replete with critical sagacity and inexhaustible invention, but he possessed also (and of this no man was more unconscious) a hand unequal to the difficulty of embodying his own conceptions. His characters are almost every where excessive. They are in perpetual torture. They never know repose. The instructions of Hamlet to a Player, that "in the very torrent, tempest, and whirlwind of passion, he must acquire a temperance that may give it smoothness," are no less importantly applicable by every Painter, and most especially by any worshipper, as Fuseli devotedly was, at the shrine of Michael Angelo.

The public taste, however, in England has never yet been so alive to the claims of Historical Painting, as to make it an object of universal interest and permanent favour; or a source of effectual and persevering emulation among artists in this Country. Notwithstanding the alleged bluntness and inaccessibility to flattery which have been said to stamp our national character, there is a refined species of adulation in the Art of portraiture which has been found irresistible; which has called forth and secured the almost exclusive patronage of the titled and the wealthy; and which, consequently, in this department of Painting, has raised the English School far above every other in modern Europe. For we may with

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[*] *Histoire de l'Art chez les Anciens. Par* Winckelmann. *Traduite de l'Allemand*, 4to. 3 vols. à Paris, 1790—1803. See p. 73 of the 1st Vol. at the end of Chap. iii. of Book i. where the author repeats the theory of Montesquieu (*Esprit des Loix*, lib. xiv. ch. ii. and xii. and lib. xix. ch. xxvii.) and of Du Bos. (*Réflexions Critiques sur la Poësie et sur la Peinture, 2de Partie*, ch. xiii. and xiv.)

[†] *Inquiry into the Real and Imaginary Obstacles to the Acquisition of the Arts in England.* By James Barry, R. A., 8vo. Lond. 1775.

[*] *Annual Biography for* 1826.

strictest justice pronounce of our native Painters, that they have attained excellence in those provinces of their Art which have received of their Country adequate encouragement. In depicting scenes of familiar life and such appearances of Nature as are associated with our home-thoughts and domestic endearments; or in landscape, and especially in such Pictures as recall to memory the sports and habits and occupations of British islanders, we unquestionably equal, if we do not surpass, our neighbours. The fault of deserting the lofty and the heroic for the pastoral and the homely, lies not with British artists but with British patrons. A succession of remarkable men, from Romney, who died in 1802, to Lawrence, whose death, in 1830, has deprived his Country of talents not soon to be replaced, have left us examples of genius aspiring secretly to historic eminence, but devoting the best years of life to the service of the public in Portrait-painting.

Romney. "Romney," says Fuseli, in his caustic manner, "quitted "the unprofitable visions of Michael Angelo and Shakspeare for the more substantial allurements of portrait. He divided the tributes of fashion with Gainsborough and Reynolds. History, if not absolutely abandoned, was reserved for that distant moment when satiety of gain should yield to a pure desire of glory—a moment which never came."

Blake. Blake, whose most eccentric, yet most harmless, life, has been well drawn by Mr. Cunningham, in his *Lives of the British Painters*, was an example of the indiscretion of attempting to lead the public taste by efforts unintelligible to the public eye. But Blake's originalities were near allied to madness, and probably often not intelligible to himself.

Copley. Hoppner. Owen. Copley, a native of America, admitted member of the Academy in 1786, and well known by the popular engraving of his "Death of Chatham;" Hoppner, R. A. in 1794; and Owen, R. A. in 1814, must be added to the number who, to talents in Portrait-painting, have united (and Owen more especially) higher merit, requiring only to be fostered and matured by public favour.

Sir Thomas Lawrence. In Portrait, however, the palm of modern victory has been won, and ably won, by Lawrence. With respect to colouring, he may have been exceeded. But few of any School have surpassed the graceful ease of his forms, joined to general fidelity of likeness; his combination of polished exterior with intellectual character; his judicious backgrounds; and his consummate arrangement of light and shade. His was indeed a courtier-pencil, and could elevate at will features almost "innocent of meaning." In his "Satan arousing the fallen Angels," he has left a solitary proof that he shared at one time with Fuseli a draught of inspiration from the fountains of Miltonic Poesy; and he was certainly ambitious of the higher Historical honours of his profession. He possessed a charm of natural eloquence which will long be remembered by all who witnessed it, and which enabled him, from his chair as President, to enforce with admirable clearness and effect, the course of study best adapted to advance the Art. We must not neglect to add, that while few were more accessible or more persuasive in words, none could be, in deeds, more actively munificent towards the cultivation and reward of real merit. Sir Thomas Lawrence was born in 1769, the same year with Owen, and was admitted R. A. in 1794.

Harlow. His pupil Harlow, who died in 1819, at the premature age of thirty-two, was likely, had he lived and been reclaimed from discreditable habits, to have risen into similar estimation. The clever picture "the Trial of Queen Katharine," by this artist, is well known. His facility of hand was extraordinary. While at Rome, during the year before his death, he excited the admiration of the whole city, by completing, in eighteen days, a valuable copy of the "Transfiguration" of Raffaele, of the same size with the original.

Sir He Raeb Another name which belongs to the list of eminent British Painters in Portrait, is that of Raeburn, R. A. in 1821. He was an example, as well as a patron, of the Art among his countrymen of Scotland; presided in an Academy of Painting at Edinburgh; and was knighted on the occasion of the visit of George IV. to that city. He died in 1823.

Dawe. The fame on the Continent of our artists in Portrait-painting has been in no instance more conspicuous than in that of Dawe, an artist of some talent, (R. A. in 1814,) who migrated to Russia, and is reported to have realised £100,000. He died in 1829, shortly after his return to England.*

Bird. Edward Bird was admitted an Academician two years after the last-mentioned artist, and died in 1819. He was self-instructed, and had been singularly happy in painting ballad subjects and popular scenes of common life. But he aspired, too late, to a more elaborate style of Art for which neither education nor experience had qualified him, and his last attempts were failures.

It would be invidious to select from works of living Painters further evidence to prove our artists in no respect inferior to such of our rival neighbours as adopt the same walks of Art. We shall, therefore, conclude these brief memoirs with one further example of departed merit, and shall only recall to our readers the memory of a rising artist, Bonington, not long deceased, whose early celebrity, both abroad and in his native Country, held forth the promise of a distinguished career. **Boningto**

That the English School, however, has done its utmost, we are very slow to believe. Progressive efforts, both by artists themselves and by individuals of rank and influence, have now for eighty years been making for the advancement of public taste; the only safe foundation on which any hope of success in Art can ever be raised. Some ground has been gained. A taste for good portraits is not bad taste. We have mentioned the institution of the Society of Arts. It was founded in 1750. Next arose, in 1769, the Royal Academy. In 1805, a Society, at the suggestion of a liberal baronet, Sir Thomas Barnard, was incorporated for the encouragement and improvement of British artists, which continues to flourish under the title of the British Institution. Other Societies, for like purposes, both in the metropolis and in the principal towns of the united Empire, might be here enumerated. Galleries have been opened. Bourgeois, R. A. in 1792, Painter to the then King of Poland, who conferred on him the honour of knighthood, left, at his death in 1811, a very fine collection, which forms the well-known public Gallery at Dulwich College. At Cambridge, the Fitzwilliam Gallery, subsequently founded, bids fair to introduce an acquaintance with this pure source of intellectual refinement into our seats of learning. And at length **Sir Pa Bourge**

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* "His remains were interred in St. Paul's Cathedral, attended by a large *cortège* of artists and literary men, the Russian Ambassador and Sir Thomas Lawrence (the latter of whom was so soon after to be borne to the same spot) acting as pall-bearers." *Obituary. Gent. Mag. for Feb.* 1830.

our Legislature, by the purchase of the Elgin marbles, followed by the establishment, in May, 1824, of a National Gallery of Pictures, has gradually drawn the public eye to critical examination of some of the sublimest works of Art, familiar hitherto to few, and to the million utterly unknown. Opportunity, also, is thus presented to all future benefactors, who, like the late Sir George Beaumont, are honourably ambitious to bequeath their works and collections to their Country. When these and other various means and instruments of forming and improving public taste in England shall have had due leisure for operation, we expect with confidence far nobler and far higher labours of native genius; and, to use the words of the Committee of the British Institution, 1805, "we feel no apprehension but that the spirit of the British artist will be awakened and invigorated, whenever a free and fair scope shall be given to his talents; whenever he shall be stimulated by the same patronage as that which raised and rewarded the Italian and Grecian masters."

THEORY AND RULES OF THE ART.

Some information both as regards Theory and Practice, in the Art of Painting, may be looked for, annexed to the foregoing Historical account. This expectation, as far as is consistent with our limits, must be answered: while we, at the same time, remind the reader, that the efforts of the Encyclopædist cannot fairly be presumed to afford means of complete proficiency, but rather to point out, on subjects of this kind, such authorities as may be consulted and followed with advantage to the student. Indeed, this Art, and that of Music, as well as many others, are to be taught perfectly only by a living teacher, who disciplines the eye, the hand, or the ear by repeated trials; and with his pencil, or upon his instrument, exemplifies every precept as he proceeds. Elementary reading, without actual practice, is either altogether unintelligible, or is always likely to mislead. No Treatise upon Swimming, or upon Horsemanship, was ever yet of itself sufficient to make even an indifferent rider or swimmer: nor would any pilot, in his senses, intrust his helm to the mere theorist (however skilful theoretically) in Navigation. To instructors in the Art of Painting, the same observation peculiarly applies. With this understanding, therefore, that we are not expected to do more than may be generally useful, and that what we do, is chiefly in the way of reference to Works which treat at large upon the subject, we shall first introduce some rules and comments on the Art of Painting, under the several heads of *Outline*, *Composition*, *Chiaro-scuro*, *Colouring*, and *Style*. Secondly, we shall proceed to mention, in chronological order, such authors and their writings as afford upon this subject the most valuable information.

Of Outline.

(1.) The first step to be firmly attained in the course of study by every artist, and without which, firmly attained, no step afterwards can be attempted with credit or safety, is *correct outline*. An Art which appeals to the eye for the truth of its performances must depend primarily for success on its adherence to the form of any objects imitated, whether of the animal creation, or inanimate, or belonging to the vegetable kingdom. For this purpose, such an acquaintance, both with Natural history and with works of human invention, must be instituted and pursued, as will lead to clear and vivid ideas of the shapes and appearances of bodies, and enable the student to draw from memory, as well as from immediate observation.

(2.) This familiarity with the visible surface of things, although it should penetrate no deeper, and should abstain from all philosophic concern about their uses and properties, yet amounts evidently to no inconsiderable share of knowledge. The landscape Painter, for example, whose correctness of outline can satisfy, or, whose degree of proficiency, at least, will not provoke the censure of Botanical criticism, must possess a multitude of facts and of ideas in common with the Botanist. The correct designer of public or private works and buildings cannot avoid Architecture and Mechanics. The Painter of animals must be experienced in Natural History. The marine Painter can make no pretences to faithful delineation without intimate acquaintance with the structure, use, and management of shipping. And, above all, the Painter of History and of the human subject, must unite anatomical precision to many other various acquirements of the highest intellectual order. We may further observe, that if this talent of the draughtsman admits him into connection with almost the whole circle of the Sciences, it is also to almost every Science an indispensable auxiliary. If it derives advantage from literary and scientific sources, it often repays, with interest, the obligation; since, but for the skill and fidelity of its professors, the most important discoveries would often fail of being generally comprehended, or even known. After premising thus much on the necessity and importance of accurate delineation, we proceed to the practical requisites introductory to its attainment. The practice of correct outline may be comprehended in two words,—Perspective and Anatomy.[*]

Definition of perspective.

(3.) Perspective may be defined, the art of representing objects on a given surface, in the same forms and relative proportions which they present in Nature to the eye, according to their respective distances from the beholder, looking from a given point, called the *point of view*.

Point of view.

Aerial perspective.

(4.) Aerial Perspective represents the several gradations, depths, and breadths of light, colour, or shadow,

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[*] *Il giovane debbe prima imparare prospettiva: poi le misure d'ogni cosa; poi di mano in mano imparare da buon maestro, per assuefarsi a buone membra.* Lion. da Vinci, *Trattato della Pittura tratto da un Codice della Bib. Vat. da Gul. Manzi* 4to. Roma, 1817, p. 50.

caused by the intervening atmosphere in objects more or less remote. Aerial perspective, therefore, relates to *Chiaro-scuro*, a further branch of the subject of Painting, which will be noticed in its proper place.

Linear perspective.

(5.) Linear perspective (which belongs especially to the branch of Art now under consideration) delineates the *outlines* only, or boundaries of objects, and represents them in the same form and relative magnitude which they exhibit in Nature, according to their respective distances, and the position of the spectator's eye.

Perspective plane.

(6.) The surface on which this delineation is made, may be plane, concave, convex, cylindrical, (as in the case of Panorama painting,) conical, or, indeed, of any given shape: but the few practical rules which our limits admit will be confined to the Art of representing objects *on a plane surface* that makes *right angles with a straight line drawn from the spectator's eye*. This plane is of indefinite extent; is supposed to intercept the rays in their passage to the eye from all objects to be represented; and is called the Perspective Plane, or *plane of the picture*. In illustration of it, let a piece of plate glass be imagined extending every way to any imaginable height, depth,* and breadth. Nothing is more manifest, than that if the rays proceeding from any object through that transparent medium, could, in their passage to the eye, be made to leave impressions on the glass at their respective points of contact, the result would be, on the transparent plane, a faithful picture of the object to be represented.

(7.) It is also equally evident, that only a certain circular portion of the plane in question is visible, the portion, namely, which contains the picture. But the remainder of the plane, or invisible portion of it beyond the circumference of the circle of vision, contains other most essential points, from which the tactician in perspective is to calculate his outlines, as well as from points in the visible surface. It is for this reason that the perspective plane must be supposed of indefinite extent.

(8.) If it be asked how the spectator can thus determine points on an invisible surface? The answer is, by removing his eye at any time from the given point of view to some other at a greater, or more convenient distance from the plane. This change of position enables him to command any portion of the surface necessary to his operations. But it is from the given point of view only that his picture is intended for inspection. The points and lines used for calculating any form in true perspective on his picture, are, like the joints and wires of a puppet-show, absolutely requisite indeed for the performance, but not designed for any eye except that of the performer. They are only temporary materials, only a scaffolding, to be removed immediately when the work they are to do is over.

(9.) Here another property of the perspective plane will have occurred to the reader, *viz.* that *the circle* upon it, comprehending all visible objects, *increases or lessens with the perpendicular distance of his eye from the plane.*

Principal distance.

(10.) It is this distance which is *principally* necessary towards determining the size of the picture, and the relative proportions to each other of objects delineated thereon. This line is, therefore, called the *principal distance.* One extremity of it is, as we have already said, the point of sight, or point of view, determined by the place of the spectator's eye. (Art. 3.) Its other extremity is its point of perpendicular contact with the perspective plane, and is called the *centre of the picture*, or the *principal point.*

Principal point.

Horizontal line.

(11.) A line drawn through this latter point, level with the horizon, determines the height of the eye in a picture, and is called the *horizontal line.* A circle, having this point for its centre, and the principal distance for its radius, will be the circle already noticed. It will be found to comprehend upon the perspective plane, the whole field of vision,—that is, will include all the objects which the eye, at that principal distance, and from the corresponding point of view, is able to take in. For from any fixed point of sight, the utmost limits of the prospect are determined by two lines, forming a right angle at that fixed point of sight.

One fourth part of the horizon seen by the spectator looking horizontally,

(12.) The prospect, accordingly, of a spectator, looking (as is supposed the case in most pictures) in a horizontal direction, embraces at every view *a fourth part of the horizon, viz.* 90 degrees, and the visible portion of the perspective plane is in all cases the base of a cone, the apex of which is the spectator's eye, or point of sight; (Art. 3;) its altitude the principal distance, (Art. 10,) and the diameter of its base equal to twice its altitude, so as to make the angle at its apex a right angle. A familiar illustration of this may be constructed by means of a card, shaped similarly to the right-angled triangle D R E, (pl. i. fig. 1,) and having a piece of wire affixed to it in the direction R W, so as to divide the angle D R E into two equal parts, (viz. 45 degrees each.) Next let the projecting portion C W of the wire be thrust through the centre of a circle drawn on a separate card, or any other flat surface, to represent the perspective plane, and let the radius of the circle be equal to C R, C E, or C D, in the triangular card. If the card be then made to revolve on the wire R W, with its edge D E applied close to the surface as above, and with C R perpendicular to it, the points D and E will be observed to move in the circle D R E W, and the lines R D and R E will, by the revolution of the card, form the right cone above described.

Plate i. Fig. 1.

Size of the picture.

(13.) Here let the learner observe, that there is no necessity for every sketch or Painting to contain the whole area of the circle of vision on the perspective plane. Let, for example, the circle D R E W (pl. i. fig. 1) be the circle or base of the right cone above described, D C its radius, being equal to the principal distance, H L the horizontal line, and C being the centre of the picture. It is at the painter's option to cut out any part of that circle from the rest, provided the principal point C, or centre of the picture, be found somewhere on his canvass. Thus, the rectangles, *g l k i*, *a b f d*, and *m n o p*, may each of them comprise a sufficient number of objects proper for the composition of a picture.

Archi ral subj

(14.) It is recommended, however, to every artist who would avoid the charge of affected singularity, particularly in architectural subjects, to keep the edges of his work quite clear of the circumference of the circle D R E W; otherwise the lines of his foreground, although perfectly correct in their original design, will appear distorted when viewed at any other principal distance than the altitude of the visual cone C R, equal to D C or C E

(15.) Still more improbable would appear any attempt whatever at delineation beyond the circle D R E W,

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* By the terms height and depth, is meant the extension of the plane above and below the level of the spectator, as by breadth is meant its extension towards his right and left.

e picture take in a tr part of t horizon.

since all beyond that boundary must be invisible to a spectator at its proper point of sight, the apex, *viz.* of the cone above described. Indeed, so essential is it to the purposes of distinct and correct outline for the artist to confine himself considerably within the extreme circle of vision, (exemplified by the circle D R E W as above,) that a much smaller circle and a much smaller cone, of which the apex is an angle of 60 degrees, has been generally adopted. To illustrate this, let the angle D R E (fig. 1) of the card above constructed be reduced to an angle of 60 degrees, *viz.* to the angle Q R S divided as D R E was, into two equal parts; and made to revolve, as in the former instance, on the axis C R representing the principal distance, and held also, as before, perpendicular to the surface used to signify the plane of the picture. The points Q and S will be found to move exactly in the circle Q *g f* S, and the sides R Q and R S of the equilateral triangle Q R S will form a cone, of which the angle at the apex will be an angle of 60 degrees. Its base will be the circle Q *g f* S, and its axis the principal distance C R as before. This inner circle Q *g f* S may be not improperly called the circle of *distinct* vision. For although it would be untrue to say, that the eye at R cannot take in objects beyond this inner circle, or even to the verge of D R E W, yet such objects are seen at best but imperfectly, and they become fainter and less decided in proportion to the extension of the base of the cone above described, until they are utterly lost in the circumference of the outer circle. These particulars cannot, perhaps, by beginners, be acknowledged without some hesitation; a circumstance not surprising when we consider the involuntary and imperceptible quickness with which any change in the position of the eye is naturally made in order to command a better view of any object. In the ordinary uses of the eyesight, scarcely, for any person, does the field of view remain the same for two moments together. Whereas the laws of perspective suppose the eye, during the process of delineation, to continue fixed immovably at one point of sight, (Art. 3, 10,) without any the slightest variation, either of its distance from the perspective plane or of its field of view. According, then, to experience in the application of perspective, *a sixth part of the horizon* (*i. e.* an arc of which the chord is equal to the principal distance) will be found the utmost that can safely be attempted in one picture. In drawing from Nature, as in the case of landscape scenery, let the learner consider himself *stationed* at one angle of an equilateral triangle, as at the angle R of Q R S, with C R for his principal distance, and Q S for the limits of his drawing. He will thus take in no more at one view than would be contained between two poles fastened perpendicularly in the ground, say, for example, three feet and a half apart, and each of them also three feet and a half distant from the spot or *station* where he is placed. In the several examples, however, which follow, we shall not find it convenient to adhere strictly to the rule just given, and shall often refer to figures drawn indiscriminately within the circle of vision, in order to obtain as much compass for practical illustration as possible.

Having so far defined the perspective plane, and settled the limits of vision, within which the representation or outline must be drawn, we have next to consider the original forms of which the outline is to be a copy, and from which innumerable rays are conceived to pass through the plane of the picture to the spectator's eye.

An original plane.

(16.) *An original plane is a plane containing any original point or line, to be copied or represented on the plane of the picture.* In what follows it will be necessary to distinguish all original planes into three classes: 1st, planes *parallel* to the picture; 2dly, planes *perpendicular* to the picture; and 3dly, planes *neither parallel nor perpendicular*, that is, inclined to the picture at less than right angles. To every original straight line, not parallel to the picture, belongs a point in the perspective plane, called its vanishing point; and to every original plane, not parallel to the picture, belong two peculiar lines, called its vanishing and its base line. (Art. 19, 20, 60, and 62.)

Of original planes the horizontal and the station plane to be especially considered.

(17.) Two original planes require especial attention; the *horizontal plane* and the *station plane*. The latter has by some been called the vertical plane, from its passing through the zenith, but as it also passes through the centre of the picture, (a point always depending on the station of the spectator,) it is better known by the term station plane. The relative situation of the horizontal and station planes may be thus familiarly explained.

Horizontal plane.

Station plane.

Suppose the spectator *stationed* at the side of a room, and looking on a wall directly opposite him, towards a number of book-shelves, one of which is exactly level with his eye.* This shelf belongs to the horizontal plane, and any number of other shelves, above and below it, are portions of its parallels. Suppose, further, these planes, or shelves, to be supported by other planes perpendicular to the horizon, or floor of the room, and let one of the supporting planes be directly opposite the spectator's eye. It will be a portion of the *station plane*, and any number of similar supports to the right and left of it, are parts of as many planes, its parallels. Every book placed in its proper, or upright position, and indeed every leaf in every book so placed, will be in a separate parallel to the station plane. In like manner, if any of the volumes are laid flat on the shelf, these, and every leaf in each, will belong to planes parallel to the horizon. So, also, if any volume lie ever so little out of its erect position, and with a leaning to the right or left, this volume will be in a separate plane, inclined to the horizontal and station planes at some angle, which it is the business of perspective to ascertain. And it is easily conceivable how any book may be placed half open in such a position, as that its cover and its leaves shall form every possible angle with each other, or with any of the planes mentioned.

(18.) When both these planes (the horizontal and station plane) and their innumerable parallels added to the multitude of others, at which, in the foregoing popular illustration, we have briefly and imperfectly hinted, are invested by the mind of the spectator with the property of expanding themselves over infinite space, he will readily apprehend that in any original object there is no point or line whatever, which does not belong to one or other of these planes, or to their parallels.

Vanishing line.

(19.) He will also understand that extending *from*

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* The horizon, in Astronomy, is described to be "formed by a plane touching the surface of the earth where the spectator stands, and infinitely extended towards the heavens." (Keill's *Astronomy*, *Lect.* 1.) To this plane the term in perspective is usually given of ground plane. (Art. 41.) The horizontal plane, properly so called, is another plane parallel to it, and passing through the spectator's eye. Both planes, being parallel to each other, vanish, of course, in the same vanishing line, namely, the line of the horizon. (Art. 19, 61.)

his eye to infinite distance, every plane not parallel to the picture will appear to *vanish* in a straight line, (Art. 61,) called its *vanishing line.*

Base line.

(20.) On the other hand, each plane in its direction *towards* him will be intersected by the plane of the picture in a line called its *base line.* (Art. 62.)

(21.) The impossibility is evident of delineating any object nearer than this base line, for which, however, a parallel is most frequently substituted. Other lines between the spectator's eye and the picture also require substitutes, as,

Line substituted for the principal distance.

(22.) I. The principal distance, which, as already defined, (see Art. 10,) must be perpendicular to all vanishing lines *passing through the principal point,* and which, as we have seen, (Art. 10, 11,) is always equal to the radius of the circle of vision. That radius is, therefore, the constant substitute for the principal distance.

Direct distance.

(23.) II. The direct distance, a perpendicular from the eye of the spectator to any vanishing line *not passing through the principal point,* and which meets that vanishing line in a point called its centre. Before we can find a constant substitute on the plane of the picture for this line of direct distance, a line must be determined, which is always to be found *on* the picture, called the central distance, being the distance between the principal point, or centre of the picture, and any other centre of a vanishing line.

Central distance being always on the plane of the picture requires no substitute.

(24.) The central distance is a perpendicular drawn from the principal point to any vanishing line. Being always found on the plane of the picture it requires no substitute.

Line substituted for the direct distance.

(25.) A right angle being made by the central distance with any radius of the circle of vision, these will be two sides of a right-angled triangle, of which the hypothenuse will always equal the direct distance. This hypothenuse, therefore, is the constant substitute for the direct distance.

Plate I. Fig. 2.

Thus any one of these three lines, the *principal,* the *direct* or the *central* distance, is sufficiently ascertainable on the plane of the picture. To illustrate the foregoing statement, let the learner describe a circle, D A X B E Z Y, which is to be supposed equal to the circle of vision. Its radius C A, on this supposition, is equal to the principal distance. Let him next draw two lines, as R S, S T, (fig. 3,) on a piece of card, meeting each other in a right angle at S, and from one of the lines let S P be cut off equal to the radius A C, (fig. 2,) or the principal distance. From the other line, *viz.* S R, let any given central distance be cut off, as S V, and the triangle S V P being cut out from the card, let it be placed perpendicularly on the circle, (fig. 2,) so as that the point S shall coincide with the point C, the side S V lie in the direction of any radius of the circle, and the side S P represent a perpendicular from the eye.

Fig. 3. The above substitution explained by a mechanical contrivance.

(26.) If the triangular card be then made to revolve on the point S, the line S V, used as a radius, will form the inner circle O I K. It is important to observe, that every point in the circumference of this circle, O I K, may be the centre of a vanishing line, to which line, as to a tangent, the perpendicular from C (*viz.* the *central distance*) may be drawn. In other words, the circumference O I K is composed of all the centres of any vanishing lines that can be drawn as tangents to it. Such as, for one example, the tangent or vanishing line B E, of which the centre is O. In this example C O is the central distance of the vanishing line or tangent B E; of which the direct distance will be equal to a straight line, drawn from its centre O to the point X, or Y, in the circumference of the circle of vision; the line X Y, being previously drawn through C, parallel to B E, or, what amounts to the same thing, drawn perpendicular to C O, just as S P, on the card, was made perpendicular to S V.

Thus, having the substitute C X for the principal distance (fig. 2) drawn parallel to the vanishing line B E, we obtain O X, the *substitute for the direct distance,* and the triangle O C X (fig. 2) will be equal in all respects to the triangle V S P, on the card, (fig. 3,) *viz.*

The side C X = principal distance, or P S.
The side C O = central distance, or S V.
The side O X = direct distance, or P V.

In the same manner any other central distance, as S L, may be set off on the line S R, (fig. 3,) and also the new direct distance P L, corresponding to it. The card may then, as before, be transferred to the circle of vision, where the point L revolving round the point S, on the card, will make the small circle M W; and L, transferred to some point, as M, in its circumference, will touch the centre of some vanishing line, or tangent, suppose D Z. To this vanishing line draw the parallel A E, through C; and then a straight line from the point A or from E to M (the centre of the vanishing line D Z) will give A M or E M, the substitute for the direct distance, P L.

Representation of an angle.

(27.) An important general principle may be here premised; and in what follows, will apply universally to the representation of angular objects, (which is, in fact, the chief business of perspective,) *viz.* that any angle may be represented by determining the vanishing points of the lines which form it. Thus the centre of any vanishing line being known or determined by the methods already stated, (Art. 24, 25, 26,) let a perpendicular be raised at that centre.

The length of this perpendicular depends upon whether the vanishing line does or does not pass through the centre of the picture. In the former instance this perpendicular is equal to the principal distance; in the latter, to the direct distance.

An example for each will explain our meaning.

1st. On a plane of which the vanishing line passes through the centre of the picture.

(28.) Let any two lines, A L, and L B, (plate i. fig. 4, No. 1.) making an angle at L, be produced to their vanishing points A and B, which in this instance are supposed to be in the vanishing line A B, passing through the centre C of the picture. Let C E, a perpendicular equal to the principal distance, be raised at C, the principal point; and an angle formed at E by two lines A E, B E, drawn from the two vanishing points. The angle A L B (with any other angle made by two lines vanishing at A and B) will always represent the angle A E B. Also, if the angle A E B be divided as in the figure by any lines, as E C, E K meeting the vanishing line, the divisions of A E B will be represented by proportionally corresponding divisions of A L B. Thus A L C represents A E C; C L K represents C E K; and K L B represents K E B.

2dly. On a plane of which the vanishing line does not pass through the centre of the picture.

(29.) Secondly, for an example in which the vanishing line does *not* pass through the centre of the picture, suppose the two lines already given as forming the representative angle at L, to have their vanishing points at F and G, in the vanishing line F G. Find the centre D, of F G, (Art. 24,) and the direct distance D R. (Art. 25.) At D, the centre of the vanishing line

F G, raise the perpendicular D H, equal to D R, the direct distance. Here, as in the last example, lines drawn from the two vanishing points to the furthest extremity of the perpendicular, will form at H the original angle represented at L. Thus the angle F H G will be represented by F L G. And any number of divisions in this, as in the former instance, may be made of the angle at H, which will be represented by corresponding divisions at L.*

presenta- n of any oposed gle.

(30.) Hence we may observe, that the vanishing point of any given line, being known, and likewise the vanishing line of the plane to which it belongs, any other line representing any proposed angle with the given line, may be drawn. Thus, if the given line be L F, and its vanishing point be F, and its vanishing line be F G, the representation of any proposed angle may be made either at L, or at any other point in the line L F. Let L be that given point. Having found, by means of the central distance, C D, the centre D, of the given vanishing line; draw at D, the perpendicular D H, equal to D R, the direct distance. Next draw H F, and at H, make with F the proposed angle, say F H G. A line, G L, joining the points G and L, will complete G L F, the representation of the proposed angle.

nishing e known joining y two nishing nts that long to it.

(31.) Also, if any two vanishing points in any vanishing line are known, the vanishing line is soon found, for it is itself the straight line uniting them. Thus, F and G (fig. 4, No. 1.) being known, F G is the vanishing line of the plane, in which any two lines, vanishing at F and G, contain the angle F H G. Or, again, the points A and B, or A and K, being known; A B is the vanishing line of the plane in which any two lines, vanishing at A and B, or A and K, form the angles A E B, or A E K, represented at L.

t the re- sentation n angle ies from original.

(32.) It will be seen from this (fig. 4, No. 1.) and numerous future examples, that the representation of an angle varies, in most cases, from its original, and is almost always larger or smaller than the angle which it represents. This is a constant puzzle to beginners. Thus the representative angle A L B is larger than its original angle at E, and the same angle F L G is much larger than its original at H. To convince any learner of this as popularly and familiarly as we can, let a piece of card be cut into the shape of a triangle of larger and more convenient dimensions than the triangle A E B, but having exactly the same angles at A, E, and B. Next, construct at E (on the card) (fig. 4, No. 2.) the angle C E B; and with C E (taken from the card) as a radius, describe on another card the circle of vision. To the side A B of the triangular card affix a piece of wire, on which it may turn as on an axis. Then applying this axis to the diameter of the circle, and keeping your eye exactly over the point C, turn the triangular card on its side A B by means of the wire, and observe attentively the various *changes* of the angle at E. At first laid flat on the circle, the real angle and the apparent will coincide, and be equal to A E B. But as you turn the card *towards* you, the apparent angle goes on increasing through an infinite series of magnitudes, such as A r B, A s B, until, after attaining its greatest possible magnitude, it vanishes in the line A B. After this, continue the revolution of the card until the apparent angle again coincides with its original at N, below the line A B. The triangular card, as it now recedes from your eye, will form another series of angles, continually diminishing, as A t B, A u B, until it equals and coincides with A N B.

plained n easy eriment.

The very same appearances will take place if the circle above mentioned be drawn on a piece of glass, to represent the perspective plane; and then the wire A B be applied, and made to revolve on the side of the glass furthest from the spectator. Infinite varieties, as before, of angles between E and N will be now observed through the glass during the revolution of the triangular card on its axis A B, receding from or advancing towards the spectator. These varieties are but so many different *appearances* or *representations* of the original angle seen under so many different aspects.

Also, if another triangle of card, constructed similarly to F G H, be made to revolve on its vanishing line, as F G, and the spectator's eye be kept fixed as before over, or opposite, the principal point C, every change of representation of the angle F H G will be given according to the situation of the plane it belongs to, vanishing in the line F G. But in this latter instance fewer of the gradations can be noticed, as many of them, those between H and L for example, (fig. 4,) will be out of the circle of vision, and consequently invisible to an eye kept exactly at that perpendicular distance from C or principal distance. (Art. 15.)

The same straight line may be common to two or more planes.

(33.) Another preliminary observation, which may give clearness to what follows, is, that the same straight line is not to be considered as confined invariably to the same plane. On the contrary, the number of planes is infinite, to all of which, in common, the same straight line may belong. Thus, the axis o n, (plate ii. fig. 2,) or C X, belongs not only to the plane of i v C, but to the plane of k w C; to the plane of S z C; and to the plane of t m C; which planes, it is evident, might be multiplied to the extent of any number of radii possible to be drawn to the centre n. The same observation is to be made respecting the line i s, (plate ii. fig. 1,) which is common to the plane i M s, and the plane H v q. The axis r u, in like manner, (plate ii. fig. 3,) is common to all the several planes that appear to revolve upon it. (Art. 86, 87.)

The foregoing definitions recapitulated and exemplified.

(34.) It will be useful here to recapitulate our definitions by a reference to plate ii. fig. 4, 5, and 6.

A D B G. (Fig. 4.) A portion of the perspective plane. (Art. 6.)

C. The centre of the picture or principal point.

O. The point of view. (Art. 10.)

O C. The principal distance, on which, as on an axis, the right-angled triangle F O R, being made to revolve, forms the circle of vision. (Art. 11 to 15.)

C R, or C F. Radii of the circle of vision, and substituted for the principal distance, being equal (Art. 11) to O C, and perpendicular to the vanishing line at its centre C.

V O X. An angle of 60°, which, by the revolution of the triangle X O V on the axis O C, forms the inner circle, or circle of *distinct* vision. (Art. 15.)

M O N P. A portion of the horizontal plane. (Art. 17.)

H C L. Intersection of the horizontal plane, called the horizontal line. (Art. 11.) It is the vanishing line of all planes parallel to the horizontal plane. (See further Art. 65.)

B O U Z K. (Fig. 5.) A portion of the station plane,

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* The perpendicular, it is to be noted, will produce the same results by being raised on *either side* of the vanishing lines A B or F G, at their respective centres.

of which the intersection I N with the perspective plane is called the station line. (Art. 17.) It is the vanishing line of all planes parallel to the station plane. (Art. 65.)

C T S and C T R. Original planes passing through the centre C, and perpendicular to the plane of the picture, but not parallel to the station plane.

C W. Line of intersection of the plane C T S, and vanishing line of all planes parallel to the plane C T S. (Art. 74.)

C L. Line of intersection of the plane C T R, and vanishing line of all planes parallel to the plane C T R. (Art. 74.)

S R N. (Fig. 6.) A portion of an original plane making with the plane of the picture the angle R S E, (to which C O P is constructed equal,) and having B S for its base line, and V L for its vanishing line, (Art. 19, 20, 64,) and for the vanishing line of all planes parallel to the plane of S R N. (Art. 65.)

P. The centre of the vanishing line V L. (Art. 75.)

P C. The central distance. (Art. 24.)

O C. The principal distance, and C P its substitute. (Art. 22.)

O P. The direct distance, and P D its substitute. (Art. 22, 25, 75.)

Practical perspective as attainable as practical geometry.

We have now generally stated the nature and position of original planes, together with the lines and points on the perspective plane, which are necessary towards correct representation. The rules and observations which follow relate to the application of these materials. To know the reasons for each rule, the student must consult his Euclid, or any geometric treatise on the subject, but to know the rules themselves may be enough for the merely practical draughtsman. As practical Geometry is all that commonly is requisite for the engineer or surveyor, so practical perspective suffices for the artist. It remains for us to give some leading examples of representation in the several cases to which the Art extends.

All cases for perspective reduced to three.

These cases may be reduced to three. i. *Planes which have no vanishing line.* (Art. 67.) ii. *Planes of which the vanishing line passes through the centre of the picture.* iii. *Planes of which the vanishing line does not pass through the centre of the picture.* But as this division will be expressed more clearly by terms referring to the illustrations we have given, we shall describe the same three cases in other words.

Case I. Of planes parallel to the perspective plane.

Case II. Of planes perpendicular to the perspective plane; which include three varieties:

1st. Planes parallel to the horizontal plane.

2dly. Planes parallel to the station plane.

3dly. Planes neither parallel to the horizontal nor to the station plane.

Case III. Of Planes neither parallel nor perpendicular to the perspective plane; containing also three varieties, *viz.*

1st. Planes whose bases are parallel to the horizontal line.*

2dly. Whose bases are parallel to the station line.†

3dly. Whose bases are neither parallel to the horizontal nor to the station line.

Of Outline.

The first case.

(35.) To exemplify the several foregoing cases. In plate ii. fig. 2, the diameters *i v*, *k w*, *s z*, *t m*, are in *a plane parallel to the perspective plane*, and consequently belong to Case I. To the same case belong, in plate iii. fig. 1, two sides of each of the four boxes, *viz.* the side in each nearest the spectator, and its parallel, the side most distant. Also two sides similarly circumstanced in the lids of the box *o p r*, and of the same box as seen resting on a different plane, of which the vanishing line is C Q.

The second case.

Of Case II. examples are abundant. The plane P *j e*, plate ii. fig. 3, is *parallel to the horizontal plane.* Also (plate iii. fig. 1) the square bottom of each of the three lower boxes, and of the box in each of the figures. (Plate ii. fig. 1, plate iv. fig. 1, and plate v. fig. 2.) *Parallel to the station plane* we have examples in the sides (plate iii. fig. 1) *d x* and *i g*, *oj* and *s k*, *x y*, &c. of the boxes there introduced. Also, (plate vii. fig. 1) in a picture-frame suspended from the point *s*.

Planes neither parallel to the horizontal nor to the station plane, but perpendicular to the picture, are represented in plate ii. fig. 2; also in plate iii. fig. 1, the bottom of the upper box, with the top of its lid, together with those sides of both which are perpendicular to the plane of the picture.

The third case.

Case III. may be thus illustrated. The planes (plate iii. fig. 1) *a b* V and *d h* Z, in the lid of the box *d f*, and the plane *x a* W, in the lid of the box *y a*, form examples of planes the *bases of which are parallel to the horizontal line.*

Again, to exemplify planes of which the *bases* are *parallel to the station line.* The base *g b*, (plate ii. fig. 3,) of the plane P *b g*, is similarly circumstanced. And, lastly, for an example of a plane *neither parallel to the horizontal nor to the station line*, observe the plane of the lid of the box (plate ii. fig. 1) *e u s i*, which vanishes in the line M L. Also, (in plate iv. fig. 1,) a similar lid *k t s e*, vanishing in the line X M. Likewise (in plate v. fig. 2) the lid *k h i w*, vanishing in the line V M.

CASE I.

Of Planes parallel to the Perspective Plane.

Rules and Observations.

(36.) That if any number of parallel straight lines be all parallel to the plane of the picture, their representations are parallel to each other.

(37.) That the representations of all equal straight lines in a plane parallel to the plane of the picture, are all equal to each other.

(38.) That if an original straight line be parallel to any straight line on the plane of the picture, its representation is also parallel to that line.

(39.) That the representation of a plane figure, parallel to the perspective plane, is a similar figure; that is, its angles are equal to those of the original, and its sides proportional. Thus, if the principal distance be divided into a number of equal parts to stand for yards, feet, or any other measure expressing the distance of the original plane from the spectator, the representation may be given of the sides of the figure according to that scale.

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* In which examples the plane is perpendicular to the station plane.

† In which examples the plane is perpendicular to the horizontal plane.

PROBLEM I.

To prepare the Perspective Plane for Case I.

(40.) Describe any circle A G B D with C for its centre, representing the principal point; and within that circle of vision, let the line E F represent a plumb-line, (or the nearest upright object in the foreground,) divided into any number of equal parts, say seven; each of which suppose, in the original plumb-line, to be one foot; and in the representation of it, as here given, to be one-fifth of an inch.

Draw to the line E F two parallels, G I, H K, at pleasure, (according to the size of the drawing, and the intended extent of the view,) and to these parallels two perpendiculars meeting them at the four points G, H, I, K. Let the sides of the drawing be next divided into equal parts, according to the scale of E F. The sides G I, H K, will represent 18 feet each. The sides G H, I K, 22 feet each. It will be manifest that these four lines, or sides of the drawing, are parallel to the horizontal (Art. 11) and station lines, (Art. 17,) and that a line drawn from any given number, as 7, and passing through the centre of the picture, to the same number on the side opposite, would be the horizontal line. Also a line through C parallel to the plumb-line, would be the station line. (Art. 17, 34.)

(41.) The lower side of every drawing is commonly called the ground line, and the plane of which it is the base, the ground plane. (See note * Art. 17.)

(42.) In sketching from Nature, a substitute for the plumb-line may occasionally be found in the upright edges of a wall or other building, the height of which is known; or in the height of any other object perpendicular to the horizon. Having now fixed at the sides of the picture the proportions of the nearest objects, or, rather, the nearest points of objects that it is possible (Art. 11, 12) to delineate upon it; let the learner next divide the principal distance (or radius B C of the circle of vision) according to the same scale. (Art. 39.) In the present example it will contain sixteen parts. So that according to the perspective plane now prepared, the principal distance (or distance of the spectator from the plane of the original plumb-line) is 16 feet; the height of his eye from the ground plane is 7 feet; and the utmost limits of his prospect along the ground line (*viz.* the side I K) produced both ways to the circumference of the circle at A and D will be about 26 feet. It is recommended to the student to practise this preparation of the perspective plane in various scales, and not confine himself to the one here given, which, in fact, must refer to many objects indistinctly seen. (Art. 15.)

PROBLEM II.

To draw (parallel to the perspective plane) any surface which shall be similar to any other surface also parallel to the same plane; and which shall represent that surface at an equal, a greater, or less distance from the spectator.

(43.) The student is expected to be familiar with the construction of regular figures, the circle, the triangle, the square, parallelogram, &c. as taught in elementary books of practical Geometry. Raise at any point, as O, in the ground line, a perpendicular; and describe a circle, O P R, the centre of which is in that perpendicular; and the radius of which is equal to any given number of the divisions on the ground plane, say three. It is required to make a representation of this circle in any part of the picture, either at the same distance, or at any other greater distance.

First part of Prob. II.

(44.) To represent the circle *at the same distance*, nothing more is requisite than, with the same radius, (Art. 37,) to make at any given point a circle of exactly the same apparent area. This done, any regular figure within the circle may be represented, such as the equilateral triangle O P R. If the sides of the original figure are parallel to those within the circle, their representations must be also drawn parallel. (Art. 36 and 38.) This is the well-known case of architectural elevations, which are drawn in conformity to a ground plan previously determined.

Second part of Prob. II.

(45.) Next, to represent the surface O P R at a *greater* distance. Take any radius, as U V, less than that of O P R, and construct a circle at the point given. The circle thus constructed will represent a breadth of six feet (the diameter of O P R) on some plane parallel to the picture at a greater distance from the spectator than the plane of O P R, (*i. e.* greater than 16 feet, the principal distance;) and it is evident that a similar figure to O P R drawn within the circle at U, according to that scale, (of U V,) will represent the figure O P R, at that greater distance.

If it is required, on the ground plane, to find the distance of the last constructed circle; draw the lines O C, T C, cutting off a portion from the ground line equal to the radius of O P R. Between O C and T C lie all the parallels to the ground line that *can be drawn less* than O T. From O T cut off O 5, equal to U V, and draw 5 S parallel to O C. The line N S equal to O 5, or U V, drawn between O C and T C, parallel to I K, will be the radius required; and will show the distance of the plane of U V on the ground plane. In other words, the surface to which U V belongs, and the surface to which N S belongs will be in the same plane parallel to the picture: and the triangle at N will be equal to its similitude at U, and will represent O P R at the distance of the original at the point N on the ground plane. It is moreover evident, that according to this new scale of N S, or U V, the same figure may be repeated in any other part of the picture. (Art. 44.) Thus will be formed faithful representations of O P R on a plane parallel to the picture, and intersecting the ground plane, of whose line of intersection N S (being parallel to the ground line) is a part.

Third part of Prob. II.

(46.) It was next required to draw the representation of a surface, parallel to the perspective plane, at a *lesser* distance than any given. This given distance must not be the distance of P R O, or of any figure drawn by the scale at the sides of the picture, since nothing *nearer* can be represented than by that scale. (Art. 21.) Let then the equilateral triangle *b m d* be the figure given, of which a copy is required at a nearer point, as N on the ground plane. Parallel at *m* to the ground line draw a straight line *m e*, equal to the radius of the circle *b m d*. Through the extremities of this parallel draw C O, C T. These lines will cut from off the ground line, a portion O T, here representing 3 feet. At N, draw N S parallel to *m e*, or O T, and meeting C T in S, N S will be the representation of a length of 3 feet, the radius of *b m d*, removed to N, on a nearer plane parallel to the picture; and having N S for part of its line of intersection with the ground plane.

(47.) It may often be more convenient to draw the scale of the ground line (or rather the scale of C B, the principal distance) on a line parallel to some line in the figure to be copied. Thus the side P O, in the triangle O P R, being equal to about 5 feet, the lines O C, P C, drawn from its extremities, will cut off N X and *b m*, representing a length of 5 feet at the distances N and *m*.

Another mode of operation for Prob. II.

(48.) Another method of determining the size of objects on a plane parallel to the picture, according to their distance from the spectator, is by dividing, or multiplying, proportionally to the distance required, any line in the figure to be copied. Thus the radius of O P R, or the line O T equal to the radius of O P R, may be used to express the distance of the required object from the spectator: and may be divided so that one portion of it shall express the distance of the figure O P R from the spectator; and the other portion of it express the distance of O P R from its intended copy. Let it be required, for example, to represent O P R at a distance of 24 feet. O T may be conceived to consist of twenty-four equal parts, sixteen of which express the principal distance, or distance of the plane of O P R; (Art. 39;) and the remaining eight the distance of the plane of O P R from that of its copy at N or U. O T, therefore, being divided into three equal parts, will express the required proportions, *viz.* two-thirds for the distance of O P R; the remaining third for the distance of O P R from the copy at N or U; and the whole (as was before said) for the distance of the plane of N from the spectator's eye. One of these two portions of O T will give the scale of the representation sought for, *i. e.* will be the size of the copy of O T at the point N. It will be that portion of O T, expressing the distance of the figure of which the copy is to be made, *viz.* the portion O 5, two-thirds of O T. This portion will represent, at N, or U, or any where in the picture, the radius of O P R on a plane parallel to the perspective plane, and 24 feet distant from the spectator.

For second part of Prob. II.

(49.) Accordingly, N S is equal to two-thirds of O T, and is a representation of a line of the same length with O T at the distance of 24 feet from the spectator. But O T measures 3 feet. N S, therefore, divided into three, will form a scale of feet for the copy of the figure O P R at N or U; or for that of any other figure on the same plane of N or U, parallel to the picture. Or the copy may be made by lines parallel to O P R, each of which is two-thirds of the length of its original.

(50.) Again, as another example, let it be required to represent a copy of the figure X Q N at twice the distance of N. The line N S, divided into two equal parts by a parallel from its centre to C O, cutting C T at *e*, will give the radius *m e* of the representation required: and *m e*, accordingly, divided into three, will be a new scale of feet for the figure copied at *m*, or for any other figure on the plane to which it belongs parallel to the picture.

For third part of Prob. II.

(51.) But if a given surface, as *b m d*, parallel to the picture, is to have its similitude represented nearer to the spectator, and consequently on a larger scale: multiply its diameter, its radius, or any other line in the figure, by *the denominator of the fraction expressing that portion of its distance at which you mean to place the given surface.* If, for example, you wish *b m*, or *b d*, or *d m*, or *m e*, to be drawn in perspective at *half* their present distance, multiply any one of those lines by 2, *i. e.* make it twice its present length. If you desire it to be one-third of its distance, multiply by 3, *i. e.* make it three times its present length. If you reduce it to two-thirds, multiply by 3 and subtract 1. If to one-fourth, multiply by 4. If to three-fourths, multiply by 4 and subtract 1. If to two-fifths, multiply by 5, and subtract 3. If to three-fifths, multiply by 5, and subtract 2. If to four-fifths, multiply by 5, and subtract 1. The quantity subtracted being always equal to the difference between the numerator and the denominator of the fraction, whenever the numerator exceeds 1.

No distanc to be attempted les than the principal distance.

(52.) In this latter operation, care must be taken that *no distance* on the picture be attempted *less than the principal distance;* (Art. 21;) for instance, if the triangle *b m d* is represented 48 feet distant from the spectator, and it is desired to represent the same triangle at a fourth part of that distance: the answer is, that such a representation on the picture I G H K, with the principal distance B C, is impossible; because a fourth part of 48 feet is a distance of 12 feet; consequently 4 feet less than the principal distance B C, and situated out of the plane of the picture, on some other plane between the spectator and the nearest object, (as O P R,) that can be drawn on the picture.

The foregoing methods accord with optical phenomena.

(53.) The optical principle upon which both the foregoing methods are founded, may be thus briefly explained. Let the eye of the spectator at E (plate vi. fig. 1) be directed towards P O, X N, and *b m*, each equal to O T, that is, to a radius of the circle O P R in the last figure: (plate v. fig. 1:) each upon planes parallel to each other, and to the perspective plane: (O P being on a surface (plate vi. fig. 1) in the perspective plane itself; X N, and *b m*, on parallel surfaces in planes beyond it:) and each at the several distances, O E, N E, and *m* E.

O E, being the distance of the picture, or principal distance, equal to C B, (plate v. fig. 1,) will be 16 feet. Consequently, N E (half as far again) will be 24 feet; and *m* E (three times the distance O E) 48 feet. It is evident that the line P O, at the distance of O, appears to the eye at E under the angle P E O. Removed to N it appears under the angle X E N; and removed still further to *m*, the same line appears under the still smaller angle *b* E *m*. These differences of its apparent magnitude are expressed on the line P O itself: its apparent length at the point of distance N being Z O; and its apparent length at the point of distance *m* being Y O. Also, observe, that P O, divided into two parts O Z and P Z, having the ratio of 2 to 1; O Z may be used to express 16 feet, being the distance O E; P Z 8 feet, being the distance P X or O N, and therefore P O (the whole line) 24 feet, being the distance N E. Or if the division is made at Y, (O Y being one-third of O P,) then O Y expresses the distance O E, 16 feet; P Y, twice that distance, 32 feet, being the distance P *b*, or O *m;* and P O expresses the whole line E *m*, being a distance of 48 feet.

(54.) It is further manifest that Y O, the representation of *b m* on the plane of the picture, must, in order to represent *b m* (half that distance) at N, be multiplied by 2, *i. e.* must be increased to the length of O Z; and that if X N be brought one-third *nearer*, or *b m* be brought to O, Y O must be multiplied by 3, *i. e.* increased to the whole length of O P. (Art. 51.)

(55.) Another remark to the purpose of our illustration is, that if O Y be multiplied by 3, (that is, increased to the length O P,) it will either represent *b m*, three times greater at the distance *m* E, or the same size at its nearest distance O E. Also that if X N be moved perpendicularly to and fro, along and between the lines m O and b P; a line drawn from X to E, (at any time during the progress of X N,) will intersect O P in some one of the several points between P and Y, and show the apparent magnitude of X N, or of its equal O P, at any point of distance between O and m. So that the line O P is at all times divisible into two parts; of which (if the whole line be used to express the furthest distance, as E m, required for the object) one part shall express the distance (as O m) of the plane of the object from the plane of the picture; and the other part shall express O E, or the principal distance. The learner will see, therefore, that the scales by which O P may be thus divided, are infinite in their variety; since every *new distance of the object demands a new scale* greater or less, according to that distance. This scale of O P, once determined, he has only to deduct the principal distance in feet, inches, or any fixed measures of length from the line O P, expressing similar measures, and graduated according to a particular scale determined by the distance of the plane of the object from E.

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(56.) Other examples (plate v. fig. 1) are added, to which all the foregoing rules and observations may be again applied. $g\,a\,c\,f\,h$ represents the gable end of a cottage, 9 feet broad from g to h, 13 feet high from g to a, or from h to f; its ridge at c, 17 feet from the ground; and the edges of its roof $a\,c$, and $c\,f$, each equal to nearly 6 feet. These dimensions are ascertained by drawing lines from C, through g and h, to the scale on the ground line, and thus at r and n on the plane of the picture will be shown, by lines parallel to $g\,a$, $a\,c$, $c\,f$, and $f\,h$, (see the dotted lines in the figure,) the magnitude of the object at its nearest representation (Art. 52) on the plane of I G H K.

(57.) Or these dimensions may be also known from a scale upon $g\,h$, drawn similar to that at the ground line, by means of straight lines from C to the divisions of the ground scale.

(58.) To represent the same figure $g\,a\,c\,f\,h$ at any greater distance, and consequently on a *smaller* scale: draw lines, g C, a C, c C, f C, h C, within which any parallels to the lines of $g\,a\,c\,f\,h$ will give the representation required; and the scale of this new representation is found by lines, as before, from C to the ground scale, dividing $t\,i$ into nine parts, representing 9 feet.

According, then, to these three scales ($i\,t$, $g\,h$, and $r\,n$) are determined, in this example, the relative sizes of the square window, and of the chimney, at the several distances of each plane: *viz.* the scale of the ground line, or $r\,n$, for the plane of the picture; the scale of $g\,h$ for the plane of $g\,h\,c$; and the scale of $t\,i$, for the plane of $t\,i\,y$.

It is evident that the side of the cottage $g\,a\,c\,f\,h$ may, (Art. 44, 45, 46,) at any distance, be represented (according to the scale of that distance) in any other part of the picture: for example, on the plane of $t\,i\,y$ it may be drawn either at the intersection with, and on the same level with the ground plane, as at L; or 18 feet higher, as at W; or 23 feet lower, as at Z.

(59.) Next, to proportion the apparent dimensions of the surface $g\,a\,c\,f\,h$ to its distance. Let the divisions on that portion of the ground line (*viz.* $r\,n$) which is cut off by producing Cg, and C h, be changed to signify the number of feet (or any other measures of length) at which the plane of $g\,a\,c\,f\,h$ is distant; say 24 feet. Out of these 24 equal parts, sixteen (the number of feet in B C, the principal distance) will be found equal to $g\,h$. Or, without altering the ground scale, $g\,h$ may be found thus, 24 : 16 :: 9 : 6, giving 6 feet, taken from $r\,n$, for the length of $g\,h$. In the same manner, $t\,i$ being compared with $g\,h$, (according to the scale of $g\,h$,) its distance from $g\,h$ is found. Multiplying 24 (the distance of $g\,h$) by 9 its length, and dividing the product by $4\frac{1}{2}$, (the number of feet which $t\,i$ measures on the scale of $g\,h$,) we obtain 48 feet for the distance of $t\,i$. In other words, $t\,i$ being equal to one-half of $g\,h$, must be twice (Art. 54) the distance of $g\,h$, *viz.* 48 feet from the spectator, the half of which, *viz.* 24, will be its distance from $g\,h$: $g\,i\,t\,h$ may, therefore, represent the floor of a room 24 feet by 9, the nearest side of which is 24 feet distant from the spectator.

A Gothic window, 18 feet high, is also represented, according to the foregoing methods, at the distance of 48 feet from the spectator. It is recommended to the student to practise the above problem with any other principal distance; that is, with any other radius to the circle of vision than C B: and not confining himself to 16 for its divisor, to choose any other number.

The student advised to draw figures and examples of his own for these problems.

Clearness and facility will also result from drawing every example on different sides of the picture.

CASE II.

Of planes perpendicular to the **perspective plane**;* which include three varieties, *viz.*

I. Planes parallel to the *horizontal* plane.

II. Planes parallel to the *station* plane.

III. Planes neither parallel to the horizontal nor to the station plane.

Rules and Observations.

(60.) That the point where the perspective plane intercepts a straight line drawn through the spectator's eye, or point of view, parallel to any original straight line, is the vanishing point of that original line.

Vanishing point.

(61.) That the vanishing line of any original plane contains the vanishing points of all straight lines in that plane, which have parallels intercepted as above.

Vanishing line.

(62.) That of the two extremities of every straight line, infinitely produced, or extended both ways upon its original plane; one extremity extending *from* the spectator, reaches a point represented in the vanishing line of that original plane. The other extremity *towards* the spectator, reaches a point in the base line of the same plane. (Art. 19, 20.) This extension of any line to its vanishing and base points is called an *indefinite representation.*

Indefinite representations.

(63.) That all lines whatever of intersection with the plane of the picture by original planes extending *towards* the spectator are *base lines;* and all points of intersection with the plane of the picture, by lines similarly extended, are *base points.*

Base lines.

Base points.

(64.) That the vanishing and base lines of every plane are *parallel* to each other.

Vanishing and base lines parallel.

(65.) That every plane has its own base line apart from every other; but that all parallel planes have the same vanishing line. For example, the horizontal line H L (plate vii. fig. 1) is the vanishing line of all planes parallel to the horizon; and the station line B D is that of all planes parallel to the station plane. (Art.

Same vanishing line serves for all parallel planes.

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* Otherwise denominated (Art. 34) planes of which the vanishing line passes through the centre of the picture.

11, 17, 18, 34.) And, indeed, any straight line whatever, *passing through the centre of the picture*, is the vanishing line of such planes perpendicular to the picture as have their bases parallel to that vanishing line. A similar rule holds (as will be seen in Case III.) with any straight line *not passing through the centre of the picture*. It is the vanishing line of all planes parallel to each other which have their bases parallel to it, and which admit of no other central distance.

Parallels to the base are substituted for it.

(66.) That, in most instances, when the actual base line of any plane is difficult to be reached on the perspective plane, another parallel base may be substituted. (Art. 21.)

What planes have neither base nor vanishing line.

(67.) That planes parallel (as in Case I.) to the plane of the picture, having no intersection with it, *i. e.* no base line, have likewise no vanishing line. (Art. 34.)

(68.) That the vanishing and base lines become one and the same line for any plane, that, passing through the centre of the picture, is perpendicular to the perspective plane.

The horizontal vanishing line and the station vanishing line.

(69.) That, therefore, the vanishing and base lines of the horizontal plane are one and the same straight line, called the horizontal line. (Art. 11 and 17.) And that, also, the vanishing and base lines of the station plane are one and the same, called the station line. (Art. 17.)

Are perpendicular to each other.

(70.) That the horizontal and station lines intersect each other in the form of a cross at right angles at the centre of the picture. For example, the horizontal line H L (plate vii. fig. 1) is at right angles with B D, the station line.

(71.) That a perpendicular from the eye of the spectator to any vanishing line, intersects the plane of the picture in a point called the centre of that vanishing line. (Art. 22, 23.)

The centre of a vanishing line is the vanishing point of all perpendiculars to the base of its plane.

(72.) That the centre of any vanishing line is the vanishing point of all lines perpendicular to the base of the plane to which they and their vanishing line belong. For example,

In plate II.	fig. 1.	H	is the vanishing point of the line	*m t*	the original of which and its parallels are perpendicular to their base, or to	*q m*
		L		*m x*		*q m*
	fig. 2.	C		*n o*		*i v*, &c.
	fig. 3.	P		*u r*		*b g*
Plate III.	fig. 1.	C		*g f*		*e g*
		C		*j p*		*j k*
		Z		*h l*		*d h*
		V		*b h*		*a b*
		W		*y u*		*y &*
Plate IV.	fig. 1.	X		*b a*		*b e*
		V		*b f*		*b e*
Plate V.	fig. 2.	V		*a e*		*s a*
		L		*a f*		*s a*
Plate VII.	fig. 1.	C		A *n*		A X
		C		*a l*		*a b*

With many more examples which might be mentioned, and which the reader will discover for himself. The above are here given to render him familiar with the plates. He will observe that the distance between C, the centre of the picture, and any other points denoted above (in the left-hand column) by capitals, is the *central distance*. (Art. 24, 26.)

All lines perpendicular to the picture vanish in its centre.

(73.) That, consequently, the vanishing point of all original straight lines perpendicular to the perspective plane is the centre of the picture.

(74.) That the centre of all vanishing lines passing through the centre of the picture, is that central or principal point itself of the picture; and is the extremity of the line called the principal distance, which is perpendicular both to the vanishing line and to the plane of the picture. (Art. 10, 22.)

Principal point is on extremity of the principal distance.

(75.) That the centre of any other vanishing line, i. e. of any not passing through the centre of the picture, is at the extremity of a perpendicular, drawn, like the principal distance, from the spectator's eye, and called the *direct distance*, perpendicular to the vanishing line, but *not perpendicular to the plane of the picture*. (Art. 23.)

How the direct distance differs from the principal distance.

The same vanishing point serves for all lines parallel to each other.

(76.) That all parallel lines in the same plane, have the same vanishing point. For example: (plate ii. fig. 1:) L is the vanishing point of the parallels *i s* and *e u* in the same plane, and of *i s* and *q v* parallels in another plane. Again, the vanishing point is C (plate ii. fig. 2) of the line *n o*, and also of the lines *m* C, *i* C, *k* C, *s* C, *t* C, *v* C, &c. represented in the same plane with *n o*. (Art. 33.) See further the vanishing point P (plate ii. fig. 3) of *u r*, and also of its parallels *a* P, *b* P, *d* P, *e* P, &c. In like manner V (plate v. fig. 2) is the vanishing point of the parallels *i h* and *w k*, in the plane *i* V *w*, and also the vanishing point of *i h* and *s x*, parallels in the plane *s* V *i*. L is here the vanishing point of the parallels *a f*, *s i*, *e d*, and *x h*. Observe, moreover, (plate vii. fig. 1,) C the vanishing point of all the perpendiculars to the perspective plane.

Proportions to be determined of parallel lines.

(77.) That if the extremities of any number of equal and parallel straight lines lie between two parallel straight lines, the representations of the latter meeting in their vanishing point, shall determine the perspective proportions of the former. (See Prob. II. Art. 43 to 59.)

PROBLEM III.

Prob. III.

To prepare the Perspective Plane for Case II. viz. the Case of Planes perpendicular to the Plane of the Picture.

Plate VII. Fig. 1.

(78.) Draw the straight line H L, representing the level of the horizon; and in that horizontal line, choose a point for the centre of the picture, opposite to which is the spectator's *station*. Through C draw the perpendicular B C D, to mark the intersection of the station plane with the picture. (Art. 70.) Describe, with the principal distance P C for radius, the circle D P B S. This will be the circle of vision; the base of a cone, of which P C is equal to the altitude. (Art. 12, &c.)

(79.) Or, if the line of the horizon is not conveniently found, draw B D; the original of which, by means of a plumb-line, may be at any time most accurately obtained. (Art. 40.) Then with the centre C, (the height of the eye,) on that station line, and with B C, or D C, equal to the principal distance (Art. 10, 11) for radius, describe the circle of vision as before; and draw H L through C, perpendicular to B D. Let next the parallels E G, F I to the station line, and E F, G I to the horizontal line, be drawn *ad libitum*, any where within the circle, and limiting the intended representation. (Art. 13.)

Bases of [illegible]

(80.) These rectilineal boundaries will, it is evident, be useful as occasional base lines. (Art. 21.) E F and G I occasionally as the base lines of planes parallel to the horizon; E G and F I occasionally as the base lines of planes parallel to the station plane. (Art. 17.) They may be substituted for base lines of any planes, whose vanishing lines are parallel to them. (Art. 64.) For example, E G may sometimes stand for the base line of

inting.

bases re- ent pa- lls to the are.

a plane of which F I is the vanishing line, or *vice versâ*. F E may stand for the base line of a plane, of which I G is the vanishing line, or *vice versâ*. Indeed, *any straight line parallel to the plane of the picture may be represented as a substitute for a base line* of the plane to which it belongs. (Art. 123.)

ision of rincipal ance a scale e trans- ed to the nd line

(81.) Where an exact measurement of objects is to be made, divide, as in Case I., the principal distance into equal parts, representing poles, yards, feet, or any measures of its actual length. These parts it will be convenient to set off, as before, on the sides G I, F I of the drawing. (Art. 40.)

to each cent of the are.

(82.) Where a number of angles are required to be put into perspective, it is convenient at the points B and P, S and D, to make a number of angles, from 10° upwards on each side of the radius or principal distance; *i. e.* in the present example on each side of C P, C B, C S, or C D. The lines forming these angles will intersect the horizontal and station lines; (plate vii. fig. 2;) and the points of their intersection, such as those marked 10, 20, 30, 40, &c., on H L and B D, will be the vanishing points of all lines in any planes parallel to the horizontal and station planes: (Art. 61:) according to the angle made by each line with the base line of the plane to which it belongs; or made with any parallel to that base line.

aration certain ber of shing ts.

(83.) The whole difficulty, indeed, of practical perspective, may be said to consist in drawing such a straight line as shall represent any required angle made by the original of that line with the base of the plane to which it belongs, or with any other line: and also, secondly, in representing a straight line, divided into any number of portions, according to any given ratio.

The first part of this difficulty may be termed the *division of angles;* the second part the *division of lines.*

ling s. f angles.

(84.) The dividing points of any *angle* are the respective vanishing points of the lines which divide the angle. Thus, the points C and K (plate i. fig. 4, No. 1.) are dividing points of the angle A L B, to which points the lines L C, L K being drawn divide the angle A L B into portions A L C, C L K, K L B, corresponding to the divisions A E C, C E K, and K E B, of the original angle A E B. (Art. 28.)

f lines.

(85.) The dividing point of any *line* is to be found in the vanishing line of the plane to which the line to be divided belongs; and is the point from which intersections being drawn to a scale, on the base, or on its parallel, will divide the line according to its required proportions. No example could occur in Case I. to show the division of angles; since the planes there considered are all parallel to the plane of the picture, and can contain (Art. 34, 67) no line with a vanishing point.

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(86.) But respecting the division of *lines*, it will have been evident that in Case I. *the dividing point* for all straight lines in planes parallel to the perspective plane *is the centre of the picture.* (Art. 77.) For example, C (plate v. fig. 1) is the dividing point of the lines *t i*, *g h*, *m e*, N S, O T, O R, O P, P R, X Q, *b m*, U V, &c., because C (Art. 72, 73) is the centre of the vanishing line of the plane of O C P, R C P, and O C R, as well as of the plane of O C *n*, or ground plane; to which planes the divided lines *t i*, *g h*, *m e*, N S, &c. belong, as well as to planes parallel to the picture. (Art. 33.)

Of Outline.

(87.) For we may here take occasion to observe that, as every straight line whatever is liable to be the common intersection of any number of planes; so the expert tactician in perspective will choose that plane which enables him to make his representation with most facility. (Art. 33.)

Further preparation of vanishing points for Case II.

(88.) In the preparation of the perspective plane for Case II., it will be often necessary to provide for a great many other vanishing points besides those marked on the horizontal and station lines; since the number of vanishing lines of planes perpendicular to the plane of the picture, is equal to the number of diameters that can be drawn to the circle of vision. (Art. 72, 74.) To provide, therefore, for any other vanishing line besides H L or B D, (see plate vii. fig. 1,) arcs of circles may be drawn, with a common centre C, cutting any vanishing line of Case II., as K M, at the same central distances with those marked on the horizontal and station lines, C 10, C 20, C 30, &c.

One example given out of numberless others.

Angle made by any line with the base of its plane may be known by means of degrees marked at its vanishing point.

(89.) The points thus found (in the vanishing line K M) will be the vanishing points of lines making the complements of those angles 10°, 20°, 30°, &c. with the base of the plane to which K M belongs. For example, in the graduations upon this or any other vanishing line the complement (or difference from 90°) at the vanishing point marked 10° is 80°; at the vanishing point marked 20° is 70°; at the vanishing point marked 30° is 60°; and so of the rest.

Problem IV.

Prob. IV.

To find the vanishing point, and to give the indefinite representation of a line that belongs to any plane perpendicular to the plane of the picture, and to find also the original angle made by the given line with the base of the plane to which it belongs.

Plate VII. Fig. 1.

(90.) If the given line be found to vanish in the centre of the picture, the angle made by its original has been already stated in Art. 73. Otherwise let *e d* (plate vii. fig. 1) be the given straight line. As in this proposition the base of the plane to which the line belongs (or some parallel to the base) is supposed to be known, draw two parallels to the base; one, as O C R, for a vanishing line through the centre of the picture; (Art. 72, 74;) the other, *a b*, as an occasional base, (Art. 21,) and let these parallels be so drawn as to include the given straight line between them. Then continue the given straight line at both extremities *e* and *d*, till it reaches both the parallels at *f* and O. O *f* will be its *indefinite representation.* (Art. 62.) Its intersection (marked 40°) with the first parallel or vanishing line O C will be the vanishing point. (Art. 62.) Its intersection with the latter parallel or base line *a f*, at *f*, will be the base point. (Art. 63.)

Vanishing point and indefinite representation found.

Original angle found.

(91.) Next, to find the original angle represented by O *f a*, (namely, the *angle made by the given line with the base of the plane to which it belongs,*) raise at the centre of the picture a perpendicular, as C M, to the vanishing line, and let this perpendicular equal the principal distance. (Art. 27, 28.) Join by a line, as M O, the furthest extremity of this perpendicular with the vanishing point. A right-angled triangle will thus be formed; in which, out of the two angles at each extremity O and M of the hypothenuse, the one at O opposite the principal distance is equal to the angle required in the above problem; *viz.* equal to the angle represented by O *f a*, made by the given line with the base of the plane to which it belongs: and the other at M equal to the difference of that angle C O M from 90° represented by OfC.

(92.) Both these angles at O and M, by means of parallels to C M and M O, may be transferred to the base at the point f, where we have Kfa, equal to an angle of 50° made by the original of ed with the base of the plane $faltb$; secondly, afO, the perspective representation of that angle; and thirdly, Kfm equal to O M C, an angle of 40° as marked upon the vanishing line O C R, of which latter angle the representation will be OfC as above stated, if a line, as fC, be drawn from the base point to C. (Art. 28.)

Observations connected with the foregoing problem.

(93.) The learner will here perceive that the angles of the triangle OfC are representations of those in the triangle O M C, *viz.*:

The angle OCM represented by OCf
$COM = Kfa$ ... by $COf = Ofa$
$OMC = Kfm$ .. by OfC (Art. 28, 92.)

(94.) And as the vanishing point O belongs to a side, as O C, of these triangles which is common (Art. 33) to both, so every vanishing point, as O, takes very properly the name of the angle at f or M opposite the common side O C. Thus,

if Kfa, at the base, (the angle represented by Ofa,) be	then O M C or Kfm (represented by OfC) will be
10°	80°
20	70
30	60
40	50
45	45
50*	40
60	30
70	20
80	10
90	0

The convenience also of this mode of marking the vanishing points will abundantly appear in the next and following problems.

Examples to illustrate Prob. IV. in each of the three varieties of Case II.

Thus far has been laid down in general terms a rule for the operation in Prob. IV. Examples of the rule in each of the three varieties mentioned in Case II. may now be stated.

(95.) i. To exemplify it where the *plane* to which the given line belongs is *parallel to the horizontal plane*. Let the lines representing the top and bottom of a small rectangular box at x, (plate vii. fig. 1,) be extended (since both surfaces, upper and lower, are parallel to each other) to the vanishing line H L (Art. 65) of both planes. Two lines in each will be found to vanish at a point L marked 50°, and two at a point marked 40°, on the opposite side of the perpendicular B C. Next, lines B 50° and B 40° being drawn, will show the angles made by each line with the base of the plane to which it belongs, or with any parallel to that base, such, for instance, as the ground line. (Art. 28, 66, 80.) The lines vanishing at the point 40° will be found to make an angle of 50° with their base. The lines vanishing at 50° will be found to make an angle of 40° with their base. (Art. 93.) The two books on the floor and a bird-cage at the upper part of the picture are introduced for similar illustration. The lines bounding the cover of the lowest book, will, if produced, meet the horizontal line at their two vanishing points marked 45° in the circumference of the circle of vision. An angle of 45° will consequently be the angle made by each of those lines with the base, or with any other parallel to the horizontal line. Another book above this, supporting the portfolio $albt$, has two edges of its cover parallel to the base, *i. e.* to H L, or to the ground line. These have, therefore, no vanishing point, (Art. 67, 85,) and are drawn according to Case I. The remaining edges reach their vanishing point (Art. 73) at C the centre of their vanishing line, and are accordingly perpendicular (Art. 72) to the base line of the plane to which they belong. The wires of the bird-cage being parallel to the picture, have no (Art. 67, 85) vanishing point; and being also parallel to the station line, are, therefore, so drawn by the method in Case I.: but the lines which complete its sides being in horizontal planes perpendicular to the picture (Art. 33, 87) have their vanishing points in the horizontal line; and will be found to make angles of 45° with the base line F E.

To avoid confusion from multiplicity of lines, the several indefinite representations just mentioned have not been drawn on the plate, but are left to be supplied by the learner. We shall now, however, give other examples, which, to some readers, may prove more satisfactory. Let the lines which bound the representation $tmxo$, of a square, (plate ii. fig. 1,) be produced to their vanishing points at H and L. From the extremity W of the perpendicular W C, (Art. 27, 28, 91,) a line W H, to the vanishing point of the representation mH, will give the angle W H C $= gm$B; (the inclination of the original of mt to the base gz, or to any other base parallel to it;) *viz.* an angle of 45°. Again, the angle made with the base by the original of mx may be similarly found, and ascertained to be equal to zmF; and also the angles at which the originals of qi and qv are inclined to a base drawn through q; or inclined to gz, or to any other parallel base. In plate ii. fig. 3, the sides of the parallelogram jre vanish in the points P and Q, which (as C P and C Q are each equal to the principal distance) will be found, as in the last example, and as they are found always, the vanishing points of all lines in Case II. that make 45° with their base. The square bottom (plate iii. fig. 1) of each of the three lower boxes was hinted (Art. 35) as another example. The lines em, gf, jp, kr, &c. vanish in the centre of the picture, and therefore represent right angles with their bases eg, jk, &c. (Art. 71, 72, 73.) Another box (plate iv. fig. 1) is introduced, to the bottom of which (parallel to the horizontal plane) belong the lines ba and bf vanishing at X and V, and representing, by the angles abl and fbc, the original angles P X C and P V C equal to the inclinations at b to the base lc. Lastly, the originals of the angles bae, and faz, (plate v. fig. 2,) made with the base bz, are obtained by raising the perpendicular P C at C the centre of the picture and drawing P V, P L. The original angles will be P V C and P L C. If further illustrations be required, they may be easily made by reference to the steps of the spiral staircase, pl. viii. fig. 1.

(96.) ii. To give examples in a *plane parallel to the station plane*. Of all such planes the station line (plate vii. fig. 1) B D is the vanishing line, (Art. 65,) and their occasional base line on one side is E G, or its parallel; on the other side is F I, or its parallel. The picture-frame ivg hangs by the cord isv, against the side of a room parallel to the station plane. Two sides of the frame

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* As in this particular example.

parallel to the base F I, and therefore parallel to the perspective plane, (Art. 67,) have no vanishing point, and are drawn according to Case I; but the remaining two sides have their vanishing point in the station line at C, (Art. 72, 73,) and the parts of the cord *i s*, and *v s*, have their vanishing points also in the station line, (Art. 61, 62,) each marked 55°. Fifty-five degrees subtracted from 90° will leave 35°, the angle made by *i s*, or *s v*, with the base I F; so that if either of them be continued to its base point, and at that point a parallel to P.55 be drawn, the angle of 35° will be found made by the line *s i*, or *s v*, with the base of the plane to which they belong. (Art. 91.) Again, the glass door in the opposite wall at E has its parallels to the base E G drawn according to Case I. (of parallels to the perspective plane;) but the boundary lines at its upper and lower edges, together with the horizontal divisions of the glass, have their vanishing point in the centre C of B D, their vanishing line, (Art. 72, 73,) and are therefore perpendicular to the base E G. (Art. 72, 73.) The divisions E *z*, and *y z*, of the semicircular window will have their vanishing points at 72° and 36° on the station-line; that is, E *z* inclined 18° to the base; and *y z* 54°. The indefinite representations are, in the examples following, drawn at large. Such boundaries of the planes (plate iii. fig. 1) *d z m e*, *h i f g*, *j p o*, *s r k*, &c. as are not parallel to their base line, or (what is the same thing) not parallel to the plane of the picture; will vanish in their vanishing line W V, namely the station line. And in this instance, since they vanish in C, the centre of their vanishing line, (Art. 72, 73,) they must represent perpendiculars to their respective bases *d c*, *h g*, &c. A further example occurs in plate v. fig. 1, where *g a c f h* is supposed to represent the interior of a building. Its sides *a i g*, and *f t h*, being parallel to the station plane, will have their boundaries *g i*, *h t*, &c. vanish in C, the centre of their vanishing line, (Art. 72,) which boundaries are therefore perpendicular to the bases *a g*, *f h*.

Exam- to Prob. in the variety ase I.

(97.) iii. To give examples in planes with *any other vanishing lines* than the horizontal and station lines. Observe (plate v. fig. 1) the two sides of the roof of the building *g a c f h*. The vanishing line of the plane of *f c y* must be drawn through C parallel to *c f*, and its base another parallel. (Art. 64, 80.) In like manner the plane of *c a y* must have its vanishing line drawn through C parallel to *a c*, and its base another parallel. (Art. 64, 80.) The line of the ridge *c y*, and its parallels at *a* and *f*, vanish in C, and are therefore perpendicular to the base. (Art. 72, 73.) Their indefinite representations will be *a* C, *c* C, and *f* C, and the points *a*, *c*, and *f*, their base points, provided *a c* and *c f* be used for occasional base lines. Also, of the three sides of the prism, *viz.* the side P *b d* R, the side R *d m* O, and the side P *b m* O, the first mentioned being parallel to the horizontal plane is already explained; but the two latter must have their vanishing lines drawn through C, parallel to their bases P O and O R. (Art. 64.) Their boundaries P *b*, R *d*, and O *m* vanish in C, the centre of their vanishing line, and are, therefore, perpendicular to the bases O P and O R. (Art. 72, 73.) It is evident that the indefinite representations P *b*, O *m*, and R *d*, or of any part of them, will be C P, C O, C R: and the points P, O, and R their base points. Again, (in plate ii. fi. 2,) the several planes, to all of which the line *x o* is common, (Art. 33, 87,) being planes perpendicular to the plane of the picture, must have vanishing lines that pass through its centre C, parallel to their several bases *i v*, *k w*, *s z*, *t m*. (Art. 64.) Now, as *n o*, and its several parallels *i* C, *k* C, *s* C, &c. vanish each in the centre C of its vanishing line, they must each make a right angle with, or be perpendicular to, the respective bases of each *i v*, *k w*, *s z*, &c. (Art. 72; 73.) The lid of a rectangular box, *o s k j*, (plate iii. fig. 1,) has its nearest boundary parallel to the perspective plane This is therefore the base line of the plane, comprising the top of the lid. To this base let the learner supply a parallel (Art. 64) for a vanishing line drawn through C. The indefinite representations, as here given, will vanish in the point C; and consequently will represent right angles with their base. The same result may be obtained by drawing through C a vanishing line to the plane of the lid attached to the uppermost of the boxes. The indefinite representations there drawn vanishing in C will there again represent lines making right angles with their base. But to practise himself thoroughly, let the learner make a large copy of each plate, and draw on any one of the lids of the boxes, any lines not parallel to the base of its plane: and after finding their vanishing points, by producing them to their vanishing line, let him ascertain by Prob. IV. the angles represented by them at their base points. Further examples are given in plate vii. fig. 1. Suppose on the leaf of the portfolio *a b t l* the drawing of some plan, or rectilineal figure. Each of the lines inclined to the base of its plane, as well as *e d* already noticed, (Art. 90, 91,) will have its vanishing point in O C R, the vanishing line of the plane *a b t l*. (Art. 62.) And if each line in the figure be extended both ways, one extremity of each will have its base point in the line *a b*, which, if necessary, may be extended for the purpose: and the other extremities will reach their respective vanishing points in the line O C R. (Art. 63.) There are eleven lines in the figure. One of them being parallel to O C R and *a b* (the vanishing and base lines) will have, therefore, no vanishing nor base point; (Art. 67;) but each of the remaining ten will have its indefinite representation peculiar to each. The reading-desk placed on a round table on the opposite side of the station line, is another example. In K M, the vanishing line of the plane to which its inclined surface belongs, will be found the two vanishing points of the four lines which contain the cover of the volume. (Art. 61, 62.) These four lines being produced to K C M, will reach the point marked 40 on one side of C, and the point marked 50 on the other side; and if produced at their other extremities to the base at *n*, their indefinite representations are also found, together with angles 50° and 40° made with the base line of their plane. A thousand other and, perhaps, better ways of exemplifying by similarly inclined planes, what has been here advanced, may exercise the invention of the student; such as the roof of a house, the top of a coach, the deck of a ship, &c. &c.

PROBLEM V

Prob. V.

Given the representation of any point in a plane perpendicular to the plane of the picture: to draw a straight line representing any given length from that point, and also representing at that point any given angle either with the base of the plane to which the line belongs, or with any other straight line.

(98.) Let the given point be *f*. (Plate vii. fig. 1.) Either the base or the vanishing line is supposed to be known. To one therefore or to the other of these, draw a parallel *a f b* through *f*. Through C, the centre of the picture, draw the vanishing line O C R: then make at *f*, with the occasional base *a f*, an angle K *f a*, equal to that which the intended line at *f* is to be represented making with the base line. Next raise, to the vanishing line O C R, a perpendicular at C equal to the principal distance; and from its furthest extremity at M draw M O parallel to K *f*. O will be the vanishing point of the intended line, and O *f a* the representation of the intended angle K *f a*.

Representation found of a given angle made with the base.

(99.) In some instances it may be more convenient to make the perpendicular at C *on the same side* of the vanishing line *with the given point*. (Note to Art. 29.) The rule, in such instances, is to construct the intended angle *on the same side* of the base *with its representation*. Thus O C R (plate ix. fig. 1) being the vanishing line, C its centre, and C M the principal distance perpendicular to O R on the same side with the point *f*; let K *f* be drawn between the base and the vanishing line, making with the base the intended angle K *f a*. Then M O parallel to K *f* will give the vanishing point O of the intended line: and the angle O *f a* will represent the intended angle K *f a*. It is next required to cut off, at any given point, any portion from the indefinite representation *f* O, and to divide that portion in any given ratio. Draw *k f*, making at *f* the intended angle *k f a* with the base. The portion to be cut off must first be expressed either on the line *k f*, or on the base *a f*; and may be measured from the point *f*, according to the scale of a plane (Art. 58) parallel to the picture, containing the line *a f*, or *k f*, which scale is determined as in Case I.

The same found by another method.

Let then the point in the indefinite representation *f* O, be the point *f*, for the nearest extremity of the intended section. It is required to cut off a portion that shall represent *q f*, measured from the point *f* according to the scale fixed upon. (Art. 58.) If the measurement be made on *k f*, draw (from the furthest extremity *m*, of the perpendicular *m* C) the line *m q*, cutting *f* O in *p*: *p f* will be the portion of O *f* representing *f q*.

Representation found of a given portion cut off from any line drawn to its vanishing point.

(100.) It is not necessary always to draw the base *a f* through the given point. Let the given point for example be *n*. A line from *m* through *n* will meet the line *k f* at *h*. Then measured from *h*, let the portion required be *h q*; draw *m q*, as before: *p n* will be the representation of *q h*.

(101.) If it is inconvenient to draw the perpendicular *m* C, let M C be drawn, as before, on the same side with the given point *f*. Then, with M O, (the parallel to K *f*,) or with *m* O, (the parallel to *k f*,) for a radius, and the point O (the vanishing point of O *f*) for a centre, describe an arc S M, or S *m*, which shall cut the vanishing line O R in the point S. S will be the dividing point of the line *f* O. (Art. 84, 85.) So that if *q f* be measured on the base *a f*, then a straight line S *q* from the dividing point to the base, gives *p f*, the section required. Or if, as above, the given point be *n*, then a line from S through *n* will meet *a f* in *h*; and *h q* measured from *h*, will be represented by *n p*.

Dividing point found.

Or let the point in the indefinite representation *f* O be the point *p*, for the *furthest* extremity of the intended section. First, through the given point *p*, draw *m q*, intersecting *k f*; or S *q* intersecting *a f*; and then measuring from the point *q* towards *f*, you obtain, as before, *p f*, and *p n*, representing *q f* and *q h*.

(102.) Thus, in the division of lines, the artist has the advantage of two methods, one of which may be often useful to prove or correct the other. In determining also which of the dividing points *m* or S shall be used to divide *f* O; he will find the more eligible of the two for accurate delineation, to be that point from which the dividing lines descend upon the line O *f*, so as to make angles with it the nearest possible to right angles.

Advantage of having more than one method.

(103.) A third method is by drawing diagonals to a parallelogram, of which the line to be divided forms one side. Thus let D 5 (plate ix. fig. 2) be the indefinite representation of a line vanishing at the point 5, and belonging to a plane whose vanishing line is C L; and let D E be the portion to be divided into a number of equal parts. Mark off a portion of the base, as D W, from the point D to express the intended division.

A third method of dividing any line thrown into perspective

Draw W 5; and draw, through E, B E, parallel to the base. Next draw the diagonals W E and D B. A line F H through their point of intersection, (which represents the centre of the parallelogram,) and drawn parallel to the base, or to C L, will cut D E in the point H, and represent the original of D E bisected in H. In the same manner, by drawing the diagonals of the parallelograms W D H F and F H E B, the lines D H and H E will be respectively bisected; and thus, by these repeated bisections, D E be divided so as to represent any *even* number of equal parts required.

(104.) But this method may be made equally serviceable with the two former, by extending either of the diagonals D B or W E to its vanishing point in the line C L, produced both ways to any required length. Let, for example, W E be produced to its vanishing point in C L; then divide W D, according to the scale of the plane it belongs to, (Art. 57, 58,) and according to the division you intend to be represented by D E. Choose for this purpose any point, as G, and through G draw a straight line to the vanishing point of W E. This will represent a parallel (Art. 76) to W E; and will cut the line D E in H, giving D H for the representation of G D required, and also H E for the representation of G W.

(105.) Or if it be more convenient to produce the other diagonal D B to its vanishing point, then the division D G on the base must be made in an opposite direction from the point D at I. From I draw to the vanishing point of D B, the representation of a parallel to D B, (Art. 76,) which will cut D E in H, as before.

(106.) It was next proposed to divide *p f*, (plate ix. fig. 1,) the portion obtained from O *f*, *according to any given ratio*. For this purpose let a division be made of *q f*, either on the base, or on *k f*, by a scale adapted to the distance of the plane which contains the given point *f* from the spectator, (Case I. Art. 49—58,) and let *q f* be separated into the intended number, and according to the intended ratio of parts, say 5 equal parts. If these 5 parts be measured from *f* upon *k f*; then 5 lines from *m* to each division of *q f* will cut *p f* into the representation of the 5 equal parts. Or if the five sections be measured from *f* upon the base, along *a f*; then 5 straight lines from the dividing point S in the vanishing line, will divide P *f* exactly as before.

The abov division made ac- cording t any give ratio.

(107.) The student will observe that if *q f* be *multiplied*, instead of *divided*, and be increased to any extent, *p f*, its representation, will be proportionally enlarged. Also, that this work of division, or of multiplication, may

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…, which begin …ither ex…ity of line.

begin from either extremity of the given line; from p as well as from f or n; provided the point q be first found, by a line from the dividing point S through p to the base, or from m through p to $k\,f$.

…dly, by …b. V. …epre- …another making given …le with line …d as …ve.

(108.) It was further required to draw, at the point f, a line representing *any given angle* with O f, or $p\,f$. Here the learner must revert to what was stated in the last problem concerning the representation of angles. The angles (Art. 93) of the triangle O C M (plate vii. fig. 1) were stated to be represented by the angles of the triangle O Cf. So, in the present instance, (plate ix. fig. 1,) if a line fC be drawn, it will represent a perpendicular to the plane of the picture. (Art. 73.) Then the angle O f C will represent the angle made by the original of fO with that perpendicular, *viz.* the angle O m C or O M C; and O C f will represent the right angle O C M, or O Cm. In like manner, if any other line, such as $f\,x$, or f R, be drawn, not representing perpendiculars to the perspective plane, but having vanishing points on either side of C, in the same vanishing line with that of O f: any two of these lines, making any angle with each other at the base point f, and being produced to meet the vanishing line, will cut off a portion of it, and make, with that portion of it, a triangle. And of this triangle, the three angles shall represent corresponding ones in another triangle, which has the same common portion of the vanishing line for one side; and an angle opposite that side at m, or M, the original of the angle made by the two indefinite representations at f.

Thus, in the figure, the angles

$$\left.\begin{array}{l}\text{of the triangle O}\,x\,f\\ \text{of the triangle O C}\,f\\ \text{of the triangle O}\,f\,\text{R}\end{array}\right\}\begin{array}{c}\text{represent}\\ \text{those of}\end{array}\left\{\begin{array}{l}\text{O}\,x\,m,\text{ or O}\,x\,\text{M.}\\ \text{O C}\,m,\text{ or O C M.}\\ \text{O}\,m\,\text{R, or O M R.}\end{array}\right.$$

Consequently, of these three triangles, the three several angles at f represent their corresponding angles at m, or M; *viz.*

$$\left.\begin{array}{l}\text{The angle O}\,f\,x\\ \text{The angle O}\,f\,\text{C}\\ \text{The angle O}\,f\,\text{R}\end{array}\right\}\text{represents}\left\{\begin{array}{l}\text{O}\,m\,x,\text{ or O M}\,x.\\ \text{O}\,m\,\text{C, or O M C.}\\ \text{O}\,m\,\text{R, or O M R.}\end{array}\right.$$

(109.) To draw a line, therefore, which shall make a given angle with the indefinite representation O f, let the line m O, or M O, first be drawn to the vanishing point of Of, and let the intended angle be then made at the point m, or M, with the line m O, or M O. This line will cut the vanishing line in some point, as x, or C, or R. The point of this intersection is the vanishing point of the new line required to be drawn from f, (Art. 84.) and the angle made by that line with O f will represent the required angle.

…er …d for …pre- …ion.

(110.) Another method is, to make the intended angle at the point f upon the base. In this process, the angle made by the original of Of with the base must be expressed by a parallel, $f\,k$ to m O, or f K to M O; and the intended angle, as $k\,f\,w$, or KfW, being added to $a\,f\,k$, or $a\,f$K, let the perpendicular at C (m C or M C) be raised, as before, equal to the principal distance. Then, from the point m, or M, let M x be drawn parallel to fW; or let $m\,x$ be drawn parallel to $f\,w$: the point x will be the vanishing point of the new line $f\,x$, making the representation O$f\,x$ of the intended angle $k\,f\,w$, or KfW, O $m\,x$, or O Mx.

Increase or reduction may be represented of any angle, to any proposed number of degrees, minutes, seconds, &c.

(111.) It is manifest that the angle KfW, or $k\,f\,w$, O M x, or O $m\,x$, may be constructed of any size, and divided accordingly: consequently, that $x\,f$ O may be divided into as many representative angles as there are vanishing points between O and x. Also, that as any angle may be reduced, so may it by the foregoing method be increased. If the number of degrees are marked with accuracy, the practitioner will have less trouble in the process. For instance, the number of degrees at O being known, if he intends 10°, or 20°, or any other number to be the angle represented, he reckons along the vanishing line from the point O, (either way, as occasion shall require,) counting the point O for zero. The number marked at O in the diagram here drawn, is 40°, and a line is to be drawn representing an angle of 5°, with O f at the point f, on the side nearest C. The interval, therefore, of 5° will be 5° short of 40°, *viz.* 35°. So, if the angle was to be made on the side of O f, furthest from C, the interval would be 5° more than 40°, or 45°. It will be seen (Art. 89, 94) that the angle O $f\,a$ represents 50°; the angle O$f\,x$ 5°; and $x\,f\,\text{R} = 35 + 40 = 75°$.

(112.) According to the preparations of the perspective plane hitherto given, each division graduated on the vanishing line generally counts for 10°, but it seems scarcely necessary to remark that a graduation, more or less minute, must be adopted as circumstances require it. Some examples of the three varieties in Case II. may be now acceptable to the learner.

Examples to illustrate Prob. V.

i. On planes parallel to the horizontal plane.

(113.) i. On a plane *parallel to the horizontal plane.* The box $d\,h\,e\,g\,f\,m$ (plate iii. fig. 1) rests on a square bottom $e\,m\,f\,g$, which is parallel to the horizontal plane. The lines therefore, $e\,m$ and $g\,f$, must be constructed to represent originals equal to $e\,g$. For this purpose, draw the line $e\,w$ at the point e, making with the base or its substitute $e\,g$, (Art. 21,) the angle $w\,e\,g$, *viz.* the angle made by the original of e C, with the base of the plane to which it belongs; which angle, in the present instance, is a right angle. (Art. 72, 73.) Next, from the extremity N of the principal distance (perpendicular (Art. 27, 98) to the vanishing line H L of the plane of e C g) draw N w, which will cut the indefinite representation e C in the point m, through which $m\,f$, a parallel to $e\,g$, will complete the representation $e\,m\,f\,g$ of the square bottom of the box.

Perpendiculars at m and f to the ground plane (in other words, parallels to a plumb-line, or to the station line) will cut d C and h C in the points i and z, and will thus complete the upper square of the cube. Or, if the process, by means of a diagonal, is preferred, let the diagonal $w\,g$ be drawn, to which a parallel N H will cut the vanishing line H L in H, the vanishing point of the diagonal $g\,m$, and representative of $w\,g$. Having so found the point m, proceed as before. Three other boxes, purposely drawn at various distances, afford similar examples.

Again, (plate ii. fig. 1,) the square bottom $t\,o\,x\,m$, of which the boundaries vanish in the points H and L, is found by drawing F m at the point m, so as to make the original angle F $m\,z$ with the base; then by completing the square on mF, and afterwards its representation by lines from W to B, K, and F, which will form intersections at t, o, and x. Or, the point t may, in this example, be found by a diagonal through x, parallel to its original B F; (Art. 38;) since B F is here parallel to the vanishing line. Or, 3dly, the point x may be obtained by a portion of the base line $m\,g$ equal to $m\,z$, and on the opposite side of m. It is manifest that whatever be the angles made by Bm, or

$F m$, with the base line, lines parallel to them at W (Art. 84, 109) will give, on the vanishing line H L, the vanishing points of their indefinite representations m H and m L.

Another method (plate iv. fig. 1) is shown for the representation, $a x f b$, of a rectangle; by finding the indefinite diagonal $b y$, and drawing through any point in it (as x) lines from X and V, (the vanishing points,) cutting the indefinite representations b X and b V in points a and f corresponding to the proposed point x. The point y is obtained by dividing the angle X P V into portions X P y and y P V, equal to the angles to be represented at b, on each side of the diagonal. In this example, the original of $a x f b$ being a square, its diagonal will bisect each angle; consequently, the angle X P V must, to obtain the point y, be bisected by P y.

Representation of a circle.

A similar illustration is given in the rectangle (plate v. fig. 2) $a e d f$. An example, in plate viii. fig. 1, is adduced of a circle divided into thirty-six parts of 10° each, to be represented on the ground-plane. The diameter 1, 19 being drawn, together with eighteen parallels, 2, 18; 3, 17; 4, 16, &c. (nine on each side,) will cut the base line A B (Art. 41) in nineteen points, from each of which let an indefinite representation be drawn, which, in the present example, (since their originals are drawn perpendicular to the base A B,) will vanish in T, the centre of the picture. (Art. 73.) At that centre T, let a perpendicular (Art. 27, 98) be raised equal to the principal distance, and from its extremity, as in former examples, let a line be drawn to the original point R; this will cut the indefinite representation 19, T, in a point representing the centre, from which radii drawn to the vanishing points X, XX, XXX, &c. will intersect the several lines vanishing in T at the points 2, 3, 4, &c.; or, lines from the further extremity of the principal distance, (or perpendicular raised at T,) may be drawn to the thirty-six points in the original circle at R; and these dividing lines will intersect the parallels vanishing at T in corresponding points, 1, 2, 3, 4, &c.

An example is given (plate ix. fig. 3) of twelve lamps suspended from twelve points, equidistant from each other, in the circumference of a circle. Let i be its centre, and i 12 its radius. And let the twelve points to be represented for the suspension of the lamps be numbered 1, 2, 3, &c. corresponding to the number affixed to each lamp. Straight lines from M, as M 1, (or M g,) M 2, M 3, M 4, &c. to the twelve points in the circumference of the circle will cut the corresponding indefinite representations of the parallels vanishing at O (Art. 76) in the twelve points of suspension. Thus, let it be required to find the point a for the suspension of the lamp No. 1. Draw the base $v l$ parallel to O R. (Art. 64.) Choose a point, as g, for the original suspension point of No. 1 to be represented. Also choose some point in the vanishing line O R, as O, for a vanishing point of the parallels necessary to the representation of the circle. (Art. 76.) Draw M O, and through any points in the circle draw any number of straight lines parallel to M O. In the present example, the number is twelve, *viz.* the parallel l 4, and eleven others to the left of it. All these parallels are drawn through the twelve original points of division. Next, from the point u, where the parallel $g u$ cuts the base, draw the indefinite representation u O. Then draw from M, (the dividing point,) the straight line M g, to the original point g. M g will intersect u O, in the point a, the representation of g; and a, consequently, will be the point from which the lamp No. 1 is suspended.

In like manner, the other indefinite representations being drawn to O from the several points of intersection on the base $v l$, the remaining eleven points may be found for suspension of the lamps marked 2, 3, 4, &c. Thus the indefinite representation z O is intersected by the line M 2; the indefinite representation l O by the line M 4; and the indefinite representation v O by the line M 10. These intersections are the suspension points for the lamps No. 2, No. 4, and No. 10. So also of the rest.

(114.) It is evident that when all the several required points in the circumference of the representation have been by this process obtained, radii may be drawn from its centre to each of the twelve or more divisions; and that these radii will be the representations of corresponding radii in the original circle g 2, 3, 4, &c. The centre of the representation is easily found. Join any two opposite points, as 6, 12, in the original circle. Find then the vanishing point of the representation of that diameter. In the present instance, that original diameter is perpendicular to the base $v l$. Its representation, therefore, will vanish in the centre of its vanishing line, and its vanishing point (Art. 72) will be C. Lastly, a line M i will cut the indefinite representation x C in s. This point s, accordingly, will represent the centre of the circle.

To complete the figure: draw now $s y$ representing a parallel to the plumb-line; (Art. 40, 79;) and choose a point, as r, for the centre of the plane of the upper surface of the lamps, which are here supposed to be of exactly similar and equal dimensions, and to be suspended by cords or chains of equal lengths. Choose another point, as y, for the centre of the plane of their lower surface. Lines through r and y drawn to the vanishing points of the six diameters of the representation will cut off from each of the twelve parallels to $s y$ a portion representing the apparent size of each lamp, according to its distance from the spectator. Of the twelve points in the circle 1, 2, 3, &c. the nearest to the perspective plane is here numbered 12. The most distant is numbered 6. The lamp No. 12 will therefore be represented largest; the lamp No. 6 smallest; and the other ten of intermediate sizes. The proportions of all are obtained by reference to a scale on $r y$; since the axis $s y$ is common to the six planes s 3 y 9, s 2 y 8, s 1 y 7, s 12 y 6, s 11 y 5, and s 10 y 4. Also $s y$, being parallel to the plane of the picture, may be used for an occasional base line of any of the planes to which it is common. (Art. 33, 80, 87, 123.)

(115.) Here, then, is afforded an example of a number of lines making various angles with the base of the plane to which they belong, and with each other; *viz.* twelve radii drawn from s to the points of suspension, each making with its adjacent radius an angle of 30°. This number of radii may at any time be increased according to any fresh division of the original circle g 2 3, &c. By extending any two radii to their vanishing points on O R, the value of the angle between them will be shown. The vanishing point of the line $d p$, for instance, is at 30°, and that of the line $a s$ at 30° on the other side of C. Therefore $30 + 30 = 60°$ will be the value of the angle represented by $a s d$. In like manner, is valued the angle $b s a$ formed by $b s$ vanishing at 60°, and $s a$ vanishing at 30°. $60 + 30 = 90°$ will be the

inting.

value of the angle represented by $b s u$. Observe, that the value of any angle, if the two lines vanish on different sides of C, (*i. e.* of the centre of their vanishing line,) is determined by addition; but if on the same side, by subtraction. Thus $b s$ vanishes at 60°, and $d s$ at 30°; $60 - 30 = 30°$ will be the value of the angle represented by $b s d$.

Also it will be observed that in order to represent a circle, it is not always, as in this example, necessary to divide the circumference of the original into *equal* parts, but that any lines drawn arbitrarily, provided they be parallels to the line that determines their common vanishing point, (which line is here the line M O,) will answer the purpose; because their indefinite representations will be always proportionally intersected by the dividing lines from M in some corresponding point in the circumference. Thus the point f is represented by the point c, formed by the intersection of the dividing line M f with a line x 9 (supposed drawn at random) parallel to M O.

her examples in first variety of Case

(116.) Another application of Problem V. to the case of a plane parallel to the horizontal plane, appears at an opposite part of the plate, (fig. 4,) in the outline of a small footstool. Through the point b (the nearest corner of the projected rectangle $b g j o$) draw the occasional base $d c$ parallel to O R, (Art. 64,) and make $b d$ to $b c$ in the same ratio as are to each other the two sides of the original rectangle; according to a scale (see Case I.) adapted to the distance of the point b from the spectator. (Art 39, 58.) Suppose the vanishing point of one side, $b g$, be the point marked 30°. The complement of 30 is 60°. The other side, $b o$, therefore, will vanish at 60°, on the right side of C, on the vanishing line O R. Find the dividing point of the indefinite representation b 30, (Art. 101,) and cut off $g b$, according to the scale of $b d$, determined as in Case I. Then find the dividing point of the other indefinite representation b 60, and cut off $o b$, according to the scale of $b c$ or $d c$. The lines o 30, and g 60, will intersect each other at j, and complete the top of the stool; and if a diagonal, as $b j$, be drawn, it will meet O R at some vanishing point between 30° to the left and 60° to the right of C.

(117.) The vanishing point of this diagonal is regulated by the ratio which the two adjacent sides of the rectangle bear to each other. If they stand to each other in a ratio of equality, then, $b d$ being equal to $b c$, the rectangle will be a square; and the diagonal $b j$ will meet O R at a vanishing point marked 15°, *i. e.* midway, or 45° from the vanishing point of $b g$, or $b o$, reckoning to the right and left from those points as from zero.

But if one side, as $b c$, is greater than the other, then the angle represented by $g b o$ must be divided unequally; the two parts of it having the same ratio to each other as $d b$ has to $b c$. The dividing point of this angle (Art. 84) will be the vanishing point of the diagonal that passes through it, represented here by $b j$. To illustrate the above, let the whole line $d c$ be divided into as many parts as there are degrees in the original of the angle $g b o$, *viz.* into 90 parts. Let 30 parts be allowed for the side $d b$, and 60 for the side $b c$. Since the vanishing point 30 has been given or chosen for the side $g b$, representing $d b$, and since the angle $g b o$ has been given as representing 90°: the sum of 90° (*viz.* $30 + 60 = 90$) will bring the vanishing point of $b o$ considerably to the right of C, and fix it at 60° to the right: and the diagonal $b j$ will vanish at 30° to the right, dividing (by a line, m 30, drawn to that dividing point) the original right angle, 30 m 60, into two shares: one, 30 m 30, an angle of 60°; the other, 30 m 60, (to the right of C,) an angle of 30°. And these two shares will correspond to the two divisions of the line $d c$, and to the angles represented by $j b g$ and $j b o$ formed by the diagonal with each side of the rectangle: that is, the share $j b g$ (representing 60°) will correspond to the side $b o$, representing sixty parts of $d c$; and the share $j b o$ (which represents 30°) will correspond to the side $b g$, or the representation of the *remaining* thirty parts of $d c$. Let the learner, for the sake of practice, draw this diagram above as well as below the vanishing line; according to each variety of Cases II. and III.; and with sides of various lengths vanishing at any other points than those in the above example. For a reason before stated (Art. 95) such lines are left out in the plate as may be supplied without difficulty.

Of Outline.

Next determine the height $b l$ of the footstool, according to the scale $b d$ or $b c$. (Art. 44—46, 48.) Lines l 30, and l 60, will show the proportionate length of the legs of the stool. Observe, in this figure, that the angles at b and j are each of them representations of a right angle at m or M; since the lines 30 m and 30 M are perpendiculars to 60 m and 60 M. But parallelograms making any other angle may be chosen for examples.

The next example (plate ix. fig. 5) is supposed taken from the interior of a church, and gives the outline of two pews, similar, and of equal dimensions; the floor of each being a representation of the rectangular parallelogram $s e$ T X. Let the base $a s e g$ be drawn, and the lines s C, e C. Then find on the vanishing line O R the dividing point (Art. 101) for the representation $e t$, *viz.* the point marked 45, on either side of C. (C 45 being equal to C m, or C M.) From the point e, along the base $a s e g$, mark off $e g$, or $a e$, equal to e T. A straight line g 45°, or a 45°, will cut e C in t, and give $e t$ for the representation of e T. Or a line m T from the dividing point m, in the furthest extremity of the perpendicular m C, (Art. 98,) will make at the point t a similar intersection of e C. Through t, the line $t y$ (parallel to $s e$) will cut off $i s$, the representation of s X equal to e T: and $i t e s$ will represent the parallelogram $s e$ T X. In like manner, the floor of the pew $z u r$ is found. Let a new occasional base through the point t be drawn on a line with $i t$. A line a C will cut off from the new base a portion $y t$, representing $e a$, or $e g$, at the distance of t, (Case I.) and lines from the dividing points m, or 45°, will cut off from t C the representation of a portion equal to the original of $t e$. Then a parallel to $i t$, or $s e$, through n, will complete the rectangle as before. But observe, if the dividing point m be employed, either a parallelogram similar to $s e$ T X, and similarly placed, must be constructed on the new base $i t$, according to the scale of the plane of $i t$, (Case I. *passim*,) or the originals e T, s X must be produced at their extremities T and X to twice their length, *viz.* s X to &; and e T to Q.

Next, to represent the hexagon, and the triangular divisions of the carpet. As the triangles are equiangular, each angle will be 60°. Also, as one side is parallel to the base $s e$, the other sides will make each an angle of 60° with the base, and will therefore have their vanishing points marked 30° (the complement of 60°) on each side of C. (Art. 94.) From e to s mark off divisions each equal to the line 1, 2, (below the base,) and draw *e* 30, &c. Then through the intersections at 1 and 2 (above the base) in the representation, draw the parallel 1, 2, to *s e*; and, lastly, to complete the hexagon, the parallel 5, 6, through the intersections at 5 and 6. Observe here, as in the last example, that the angle made by the lines 1, 6, and 2, 5, crossing each other, is the representation of an angle at *m* or M, made by two radials drawn from M or *m* to two vanishing points on each side of the centre of the vanishing line, which in this example are numbered 30°.

(118.) Observe, also, that if, in an equilateral triangle, one side be parallel to the base, the vanishing point of one of the two remaining sides will be the dividing point of the other adjacent side. Thus, in *o e* 6, the representation of an equilateral triangle, lines *o* 30 and *e* 30, being drawn; the vanishing point of *o* 6 is the dividing point of *e* 6; and *vice versâ*, the vanishing point of *e* 6 is the dividing point of *o* 6.

Annexed to this figure is an outline of alternate square and octagonal divisions in the floor of the aisle. The sides of each octagon will be found to vanish in the same points with the sides and diagonals of each square. Thus *g* 45, to the left, is the vanishing point of two sides; *g* 45, to the right, the vanishing point of the two at right angles with them. Two other sides, being parallel to the plane of the picture, will have no vanishing point; and the remaining two being perpendicular to the base of their plane will vanish at the centre C of its vanishing line.* The square B *m* F K (plate ii. fig. 1) will have its indefinite representations *m* H and *m* L vanish at H and L; while the representation *t x* of its diagonal B F, will, like the original, be parallel to the base *g z*. (Art. 36.) That of the other diagonal *m* K, perpendicular to *g z*, must vanish at C. Make *g m*, *m z*, on the base, each equal to a side of the square. Find Y, the dividing point of *m* L, and with Y C for a radius, and C for a centre, cut C L in the dividing point of the indefinite representation *m* H. Lines to *g* and *z* from these dividing points will obtain the points *t* and *x*. Or, one of these points being found; a parallel to the base drawn through it will procure the other point. Or, from W, the furthest extremity of the perpendicular W C, draw lines W F, W B, which will cut *m* L and *m* H in *x* and *t*. *x* H and *t* L will then intersect each other at *o*, and complete *o t m x*, the representation of *m* B K F. Of the three squares on the ground plane (plate iii. fig. 1) the indefinite representation *g* H of the diagonal *g w*, will intersect *e* C at the point *m*: *m f*, parallel to *e g*, will next intersect *g* C in *f*, and complete the bottom of the box *e d z h g*. So of the rest. A similar process (plate iv. fig. 1) obtains the angle *a b f* representing X P V: also, *b a* and *b f*, the representations of *l b* and *b c*. Also *a f* and *a e* (plate v. fig. 2) the representations of *a z* and *a b*; and the angle *e a f* representing V P L.

An example is given (plate vii. fig. 1) of a round table. In that representation, only a fourth part of the circle is visible, (since E G I F is the boundary of the picture,) so that the quadrant D W T is sufficient for the required construction. And as no regular division of the circumference is there necessary, the parallels are drawn intersecting the base X A at random. Since they are perpendicular to X A, their vanishing point will be C, the centre of their vanishing line. (Art. 72.) To construct the lesser circle beneath the table, find the centre *n* of the table by a line B T, or S X (X A being made =A T;) cutting A C in the point *n*, and giving A *n* for the representation of A T or A X. Fix the interval A W between the parallel planes of the two circles, which (see Case I.) must be measured according to the scale of the base A X. Draw W C. A parallel *n o*, to the plumb-line or station line, will give *o* to represent the centre of the lower circle. Next subtract A W, or any required portion, from the radius of the larger circle (below the base) and describe the inner quadrant T R. Then proceed with parallels upon the new occasional base W Y, as before upon the base X A. Numerous architectural illustrations might be here introduced for delineating circular columns, walls, pavements, &c., in all which the process would be the same as above detailed.

ii. To exemplify Prob. V. on planes parallel to the station plane; the second variety of Case II.

(119.) ii. Some examples were, secondly, proposed for Prob. V. on a plane *parallel to the station plane.* The station line must now take place of the horizontal; and be resorted to, as in the last problem, for the vanishing points of all lines on any plane parallel to the station plane. (Art. 65.) The side (plate iii. fig. 1) of the cubic box, together with its parallel side *d z m e*, and four other square sides (also parallel) of the two boxes to the right of it, are all examples of planes perpendicular to the picture, and at the same time parallel to the station plane. Their vanishing line will be W V, (the station line,) and their vanishing point will be C, the centre of the picture. (Art. 72, 73.) In order to the representation *g h i f*, let the line *h g* be taken as a base; and let *h* C, *g* C, be drawn. From L, the furthest extremity of the perpendicular L C, raised at the centre of the vanishing line, (Art. 27,) lines drawn to the points *d* and *e* will intersect the indefinite representations at *i* and *f*. The line *i f* will then complete the object: or, a line *g* N to N, (the vanishing point of the diagonal *g i*, and dividing point of lines vanishing in C,) will give the point *i*; through which a parallel, *i f*, to the base will answer the purpose. An example in the preparatory plate for Case II. (plate vii. fig. 1) was given of a glass door surmounted by a semicircular window. In order to this representation, the quadrant N Q *z* is sufficient to express as much of the construction as is visible (*viz.* *z* E *y r*) in the picture. Choose a point *z*, from which to begin, according to Prob. V., the intended lines and angles. (Art. 99, 109, 110.) Draw the base Q G. Make the angle N *z* G, or N *z* Q, equal to the intended angle with the base; and to be represented at the point *z*: which angle, in this instance, is 90°. Then *z* N, perpendicular at the point *z* to the base, gives the radius, with which describe the arc N Q. Raise the perpendicular C S (Art. 27) equal to the principal distance, at the centre of the vanishing line. A straight line from the dividing point S to N, or from the dividing point D to Q, or from the dividing point B to *q*, (*z q* being made equal to *z* N, or *z* Q,) will cut the indefinite representation *z* C in the point *r*, giving *z r* to represent *z* N. Next draw parallels to *z* N, between the base Q *z* and the arc Q N; and from their points of intersection on the base, draw to C their indefinite representations. Lines from S to each corresponding point of intersection made by the parallels on the arc Q N will produce, in the same manner as in former examples, the curve Q *y r*; which, in order to receive the regular divisions *z* E and *z y*, will require its prototype N Q to be regularly divided into such portions, as that a line S J shall intersect E C, the indefinite representation of

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* Let this construction be applied to Case III., as, indeed, may most of the examples in Case II., by using only the Direct instead of the Principal distance.

J E, at the point *y*. Observe, if any number of radii be drawn from *z* to the arc Q J N; that, as the radius *z* N is represented by *z r*, so is *z* J represented by *z y*, &c. Also the angles made by these radii and measured on the arc N Q will be represented by corresponding radii intersecting the curve Q *y r*. Thus the angle J *z* N is represented by the angle *y z r;* the angle J *z* Q by the angle *y z* Q, &c.

Observe also, that the base Q G, or Q *z*, need not coincide with E G the side of the picture, but its place is determined by that of the nearest point *z*, in the representation. A line from C through *p*, will intersect N *k* at the point *k;* with which point as a new centre, and with the radius *k* N (or any other given radius) proceed as before, and construct the representation *h p* of the quadrant *h* N.

The learner will soon perceive, that the operations above exemplified are applicable not only to circles, and arcs of circles, but *to all curves whatsoever.* More examples need scarcely be given. If he is in the neighbourhood of architectural objects, he cannot fail to discover abundant examples for himself, in the arches of a bridge, of a gateway, or of an aqueduct, as well as among the numerous picturesque specimens to be collected from colleges, castles, temples, palaces, and cathedrals. Every illustration, too, which we have introduced respecting lines that belong to planes parallel to the *horizontal* plane, may be easily converted into an example of similar lines on planes parallel to the *station* plane. For this purpose, the reader need only substitute the expression *station line* for *horizontal line;* thus viewing the plate under a different aspect, and changing into a ground line (Art. 80) what before was the right or left side of the drawing. Lines which before were parallel to the station line, will, under this new aspect, appear horizontal. Thus the side I F of the picture (plate vii. fig. 1) being taken as a ground line; the boundary of the round table may be converted into an arch; the side *g* &, of the rectangular picture-frame, into an occasional base line parallel to the new horizontal D B; and the lines C & and C *g* into indefinite representations on the ground plane, its parallel.

o ex- ify V. third r of II.

(120.) The foregoing observation almost supersedes the necessity of again giving examples, as was done in Art. 97, under the third variety of Case II., namely, on a plane *neither parallel to the horizontal, nor to the station plane.* To several of the foregoing figures, let new horizontal and station lines be drawn through the centre of the picture; and let the former horizontal and station lines be no longer so named, but considered only in general as vanishing lines passing *through the centre of the picture.* Many of the examples already given will be thus available. There are, strictly speaking, but few objects in nature that are perfectly horizontal, or perfectly true to the plumb-line; whereas, the number of other vanishing lines is infinite which are included under Case II., and which form diameters of the circle of vision (Art. 11) over and above the two formed by the horizontal and station lines. Let a straight line, for example, be drawn through the centre C (plate ii. fig. 2) parallel to any diameter of the circle *i k s t v*, &c. but not parallel to the horizontal or station line.

(121.) Since the plane of the circle *i k s t*, &c. is parallel to the plane of the picture, any straight line drawn upon it may be an occasional base. (Art. 80.) Accordingly, each line drawn through C will be a vanishing line of the plane containing the diameter to which each line is parallel. Thus a line through C parallel to *i v*, will be the vanishing line of the plane *i* C *v;* and similar parallels to *k w*, *s z*, and *t m*, will be vanishing lines to the planes *k* C *w*, *s* C *z*, and *t* C *m*. And any other angle made with each base may, by the foregoing problem, (Art. 98,) be represented besides the angle 90° here represented at *n*, and at the eight points *k*, *s*, *t*, &c. Also any other portion may be cut off from the indefinite representation at *n* C, besides the portion *n o*.

The line C Q (plate iii. fig. 1) belongs also to this variety of Case II. The plane of the bottom of a box inclined to the horizon will have C Q for its vanishing line, drawn parallel to the nearest edge of the bottom of the box: which line of the edge, being parallel to the picture, may be used (Art. 80) for an occasional base. The plane of its lid requires a vanishing line similarly drawn. Moreover, if, according to what is suggested above, the line C Q be substituted for the horizontal, the lines H L and N V will furnish abundant examples as vanishing lines for the bottoms and sides of the boxes; in constructing which, the operation will be precisely similar to the mode already given.

In an introductory illustration of Case II., (plate vii. fig. 1,) a portfolio was introduced, with lines making various angles on its page *a l t b* with the base *a b*, of the plane to which they belong; and with each other. It seems sufficiently clear, from what has been explained of the process in Problem V., that any figure, curvilinear (Art. 119) or rectilinear, may be constructed and represented at any point, as at *e*, or at *f*, in that plane, according to the rules above laid down for such a representation upon all planes perpendicular to the perspective plane, or plane of the picture. We have dealt the more largely in explanatory matter to this and the foregoing problem, because the rules for similar operation in Case III., to which we now proceed, will be found, in every respect but one, (Art. 27, 29, and note to Art. 118,) exactly to resemble those we have applied to Case II.

CASE III.

Of planes neither parallel nor perpendicular to the perspective plane;* which comprise three varieties.

I. Planes whose bases are parallel to the *horizontal* line.

II. Whose bases are parallel to the *station* line.

III. Whose bases are neither parallel to the horizontal nor to the station line.

Rules and observations.

(122.) That all bases, or occasional bases, (Art. 20, 21,) of any planes included under Cases II. and III., are representations of lines parallel to the plane of the picture.

(123.) That, consequently, the representation of any straight line, of which the original is parallel to the plane of the picture, (Art. 80, 121,) may be substituted as an occasional base of the plane to which the straight line belongs.

What planes are perpendicular to the station and horizontal planes.

(124.) That all planes whatsoever, which have bases parallel to the horizontal line, are perpendicular to the *station* plane and to its parallels.

(125.) That all planes whatsoever, which have bases parallel to the station line, are perpendicular to the plane of the *horizon* and to its parallels.

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* Otherwise denominated (Art. 34) planes, of which the vanishing line does *not* pass through the centre of the picture.

Graduation of central distances.

(126.) That the vanishing lines of all planes described under Case II., have, in Case III., the additional employment of furnishing central distances (Art. 24) for such vanishing lines as belong to planes inclined to the picture. Their graduation (Art. 82, 88) is important for determining the angle made by such inclined planes with the picture, or with each other.

(127.) That any vanishing line included under Case II. furnishes, in Case III., a central distance to every other vanishing line which crosses it at right angles. (Art. 24.) Thus the vanishing line D M (plate x. fig. 1) passing through the centre of the picture, and therefore (Art. 24) included under Case II., is used for the respective central distances of the vanishing lines which cross it perpendicularly at the points D, R, Q, and M. Again, the vanishing line H T, (plate viii. fig. 1,) produced both ways to the required extent, contains on either side of the centre T of the picture, the central distances T X, T X X, T X X X, &c. of seventeen vanishing lines, each belonging to the plane of the front piece of a step in the spiral staircase.

Use of the direct distance in operations of Case III. resembles that of the principal distance in Case II.

(128.) That in general it is to be observed of Case III.; whatever operation was performed in Case II. by a substitution of some line equal to the principal distance will, in Case III., be effected by the substitute for the direct distance. (Art. 25, 29.)

(129.) Also that the operation to find the vanishing points or the dividing points for any angles, or for any indefinite representations belonging to planes under Case III., is, in all other respects, a similar process to that under Case II., except that the direct distance, or its substitute, must invariably be employed. (Art. 25.)

(130.) That as, in Case II., a perpendicular must be raised at the centre (Art. 27, 28, 29) of any vanishing line, for determining the vanishing point of any line or lines according to the angle made by them at the base, or made with each other; (see Prob. III., IV., and V.) so in Case III., a perpendicular must similarly be raised; but it must no longer equal the principal distance, it must here equal the direct distance.

Graduation of vanishing lines in Case III.

(131.) That as, in Case II., divisions into degrees numbered on each vanishing line (Art. 82) were made by radials drawn to meet it from the furthest extremity of a perpendicular which was equal to the principal distance, and which was raised at the centre of the vanishing line: so these divisions, in Case III., may be similarly graduated; but the perpendicular required for this preparation of the perspective plane must, in Case III., equal the direct distance.

For vanishing points.

(132.) That as, in Case II., portions of the above-named radials are cut off by the vanishing line; and each point of their contact with that line is the vanishing point of all indefinite representations of parallels, some one at least of which belongs to the plane vanishing in that line: (Art. 76:) so in Case III., similar points will be obtained for similar uses.

For dividing points.

(133.) That as, in Case II., the portions cut off from the above-named radials are equal to and measure the interval between the vanishing and dividing point of each indefinite representation, (which interval is measured from each vanishing point along the vanishing line on the side nearest the perpendicular:*) so, in Case III., each dividing point is similarly found in each respective vanishing line; but the perpendicular at its centre must, in Case III., equal the direct distance.

(134.) That accordingly, the interval between 30° and 30° measured (plate vii. fig. 1 and 2) on each side of the centre of the vanishing line, and also the interval between that centre and the point marked 45° each way, (which intervals in Case II. were equal to the principal distance,) must, in Case III., be made equal to the direct distance; and the dividing points (Art. 85) depending on those as on other intervals, will be regulated in every instance by them. Thus, to take the first of these instances:

The dividing point of lines, making 60° with any base, and which therefore vanish at the point marked 30° (Art. 94) on their vanishing line; will be another point, marked also 30° (Art. 118) on the opposite side of the centre of that vanishing line. (Plate vii. fig. 1 and 2, and plate x. fig. 1.) Again, in the next instance,

The dividing point of lines which make 90 degrees with, or represent *perpendiculars* to any base, (and consequently vanish at the centre of the vanishing line,) is a point on each side of that centre marked 45°, (plate vii. and x.) where a circle, having that centre, and the principal or direct distance (as the case may be) for radius, cuts the vanishing line.

(135.) That the dividing point of lines, representing *parallels* to the base of any plane, is the centre of the vanishing line of that plane. (Art. 86.) Consequently, as in Case II., the dividing point of such lines was in the centre of their vanishing line, *viz.* the centre of the picture: so, in Case III., the dividing point of such parallels to the base will be the centre of the vanishing line of the plane to which that base belongs; though no longer the centre of the picture.

(136.) That a difference is to be noticed between the graduation of vanishing lines in Case II. from that of those in Case III. It is a work, in Case III., of somewhat greater complexity. Every vanishing line not passing through the centre of the picture must be separately graduated; *i. e.* must, in its graduation, correspond to every change of the central or direct distance. But when any number of central distances are equal in length each to each, the vanishing lines they belong to will be graduated alike.

Certain planes fo shortened into straig lines.

(137.) That every vanishing line, as has been seen by the experiment of the piece of card, (Art. 32,) has one plane vanishing in it, which never presents any other appearance to the spectator but that of a straight line. It is the plane, which, produced to meet his eye, contains in Case II. the principal distance; in Case III. the direct distance. The vanishing and base lines of such a plane are always one and the same line. (Art. 68, 69.)

How to find in C III. the centres o vanishi lines.

(138.) That to find the centre of any vanishing line not passing through the centre of the picture, either a perpendicular (*viz.* the central distance, Art. 24) may be drawn to the vanishing line from the principal point; or, with the principal point as a centre, an arc may be drawn cutting out of the vanishing line a portion, which will be the chord of the arc. That chord bisected will give at its point of bisection the centre of the vanishing line. Thus, N O (plate x. fig. 1) is a chord of an arc of the circle of vision. Bisect N O in R. R will be the centre of the vanishing line. Again, with the centre C, describe an arc cutting out, any where, a portion from the vanishing line G I, situated out of the circle of vision.

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* See Art. 101 and plate ix. fig. 1, where the interval O S is equal to the radial Θ *m* or Θ M, and is measured along the vanishing line O R, in a direction from the point O towards the perpendicular at C.

Bisect the chord so cut off. The point of bisection M will be the centre of the vanishing line G I.

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(139.) That the principal distance is a mean proportional between any two central distances, expressing together the sum of 90° in the amount of their graduations; and if the two vanishing lines be parallel, the centre of the vanishing line of one plane is the vanishing point of all lines perpendicular to the other plane. For example, the principal distance C A (plate x. fig. 1) is a mean proportional between the central distances C B marked 30° and C K 60°: and (their vanishing lines E B and K I being parallel to each other) K 60 will be the vanishing point of all perpendiculars to any plane, vanishing like the plane of the ship's deck, in E B; B the vanishing point of all perpendiculars to a plane vanishing in K I.

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(140.) That out of any number of lines which are parallel to each other, and which therefore vanish in the same point, (Art. 76, 132,) any two may belong to a plane vanishing differently from that of any of the rest; but the common vanishing point of all the parallels will be the common point of intersection of the separate vanishing lines belonging, respectively, to each plane. Thus the point P (plate ii. fig. 3) is the point of intersection for the four vanishing lines of the planes to which the several parallel lines, vanishing at that point, belong; namely, for the

Vanishing line	at P*	of the plane of	*b* P *g*,	which contains,	*b* P and	*g* P.
	P Y,		*d* P *h*,	besides *u* P,	*d* P	*h* P.
	P C,		*e* P *j*,	two parallels,	*e* P	*j* P.
	P Z,		*f* P *a*,	the originals of	*f* P	*a* P.

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(141.) That an original plane, considered in relation to any other original plane, must be either, 1st, parallel to it, in which state it has been already noticed: (Art. 65:) or, 2dly, must intersect it, in which state it has been only partially noticed: *i. e.* only under Cases I. and II.

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1. One plane we have seen parallel to the picture, and the other perpendicular to the picture: in which circumstances the line of *intersection* of the two original planes is always *parallel* to the base and vanishing line of one of them. *Ex. gr.* The intersections *m f*, *e g*, *p r*, *j k*, *o s*, *z i*, (plate iii. fig. 1,) made by planes of the class just stated, are parallel to H L, the vanishing line. Almost all our plates on outline supply similar examples. Or, we have seen

h planes
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2. Both planes perpendicular, as in Case I., to the picture: in which case the vanishing lines cross each other at the centre of the picture, which thus becomes the *vanishing point of the line of intersection*; (Art. 145;) and is the point at which the actual angle made by the one plane with the other, is always formed by their two vanishing lines. *Ex. gr.* The line of intersection, *n o* (plate ii. fig. 2,) of any two of the four planes (perpendicular to the picture) vanishes in the centre C of the picture; and the angle made by any two of the planes with each other, is to be found by drawing, through C, their two vanishing lines: or by drawing at *n* or *o*, or at any point in the line of intersection, their two bases. The latter, in this example, are already drawn. Other ways of intersection now present themselves. But, respecting the laws of intersection, observe, generally,

s of in-
ection.

(142.) That when only one of two intersecting original planes has a vanishing line, the line of intersection is parallel to that line or to the corresponding base. (Art. 65, 66.) Thus, N S, (plate v. fig. 1,) the intersection of the plane of X N Q, or of U V, with the ground plane, (Art. 45, 46,) is parallel to the base I K of the ground plane. Also another parallel to I K, in the same diagram, is *i t*; *i t* being another intersection by another plane also parallel to the picture. Here one of the two planes is parallel, and the other perpendicular to the perspective plane; and our examples are drawn from Cases I. and II. Next, for an example that refers to Case III.: *d h*, (plate iii. fig. 1,) parallel to the vanishing line V R, represents the intersection of the plane *a b h d* with the plane *d h g e*. Here one of the two planes is parallel to, the other inclined to, the picture.

One plane
parallel to,
the other in-
clined to,
the picture.

Vanishing
lines paral-
lel. Both
planes in-
clined to
the picture:
or one per-
pendicular
to, the
other in-
clined to,
the picture.

(143.) That when the vanishing lines or bases of any two intersecting original planes are parallel, their line of intersection will form another parallel. Thus the base and vanishing line of the plane *l k n m* (plate x. fig. 1, No. 1.) are parallel to the base and vanishing line of the plane *o m n p*. G I, the vanishing line of the former, is parallel to Q F, the vanishing line of the latter. Agreeably, therefore, to this rule, the line *m n*, of their intersection, is parallel to G I, or to Q F, or to their corresponding bases. Also *d h*, (plate iii. fig. 1,) the intersection of the planes *d a b h*, *d n l h*, and *d z i h*, or of any two of them, is parallel to their respective vanishing lines at Z, C, and V, through which points their respective centres are joined by a line Z V passing through the centre of the picture. For it invariably follows,

(144.) That when any two vanishing lines (such as described in Art. 143) are parallel to each other; a line perpendicular to both, and joining their centres, will pass through the centre of the picture or principal point. Observe, further,

Vanishing
lines not
being pa-
rallel;
the line
of intersec-
tion va-
nishes, and
where.

(145.) That when any two vanishing lines, or any two bases, intersect each other, the planes to which they respectively belong must also intersect each other; and the line of their *intersection will vanish* at the point *where* the two *vanishing lines meet.** Thus, the centre of the vanishing line of any given plane is also found to be the vanishing point of all intersections made with the given plane by a plane perpendicular to the picture.

(146.) That for the purpose of determining the angle made by two intersecting planes with each other, the vanishing line, in most instances, must be found of a plane, which we propose to call the plane of measure. The plane of measure is a *plane perpendicular to any two intersecting planes*, which crosses perpendicularly their line of intersection and contains the two lines *measuring the angle* of their inclination to each other.

Plane of
measure.

1. Measure-
ment of the
angle made
by two ori-
ginal planes
with each
other whose
vanishing
lines are
parallel.

(147.) That when any two original planes of the class mentioned in Article 141, No. 2. intersect each other, the angle made by them with each other is measured on the plane of the picture, which is itself, in such instances, the plane of measure, being perpendicular to them both.

(148.) That when any two of the class mentioned in Art. 143 intersect each other, the angle made by them with each other is measured on the central distance of the

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* Perpendicular at P, to P C, its central distance.

* Since any one and the same vanishing point may belong to an infinite number of vanishing lines; and, consequently, any one and the same indefinite representation to an infinite number of planes: therefore, in most cases two vanishing points at least must be found, in order to determine whatever plane is common to or contains the two lines vanishing in those points. (Art. 31.) But in case only one point be given; then the angle of inclination to the picture must also be given, made by the plane that contains the original line vanishing in the given point. See Prob. IX.

vanishing line (graduated as in Case II. Art. 126) of one or both planes; which central distance, it will be seen, is part of the vanishing line of the plane of measure. This measurement may happen in three ways.

1. If one of the parallel vanishing lines pass through the centre of the picture, the angle so measured is that contained *between the direct and the principal distances.* Thus the vanishing line G I (plate x. fig. 1) is parallel to H C, the horizontal line. Its central distance C M is marked 55° to express the angle C H M contained between M H the direct, and H C the principal distance. Consequently, the plane of which G I is the vanishing line is found to make an angle of 55 degrees with the plane of the horizon.

2. If neither of the two parallel vanishing lines pass through the centre of the picture, and they are situated on different sides of that centre; the angle made by their two planes with each other is the *sum* of the angles graduated on their two central distances. It is the angle contained *between their two direct distances.* Thus the last-mentioned vanishing line G I has its central distance graduated 55°: that of the vanishing line N O, on the other side of the centre of the picture, has its central distance marked 25°. Consequently, the original plane of G I makes with the original plane of N O an inclination of 55° + 25°, or 80 degrees, being the angle contained between R H and H M, the two direct distances.

3. If these two parallel vanishing lines lie on the same side of the centre of the picture, the angle of their inclination to each other is expressed by the *difference* of the numbers graduated at the extremity of their two central distances. It is the angle contained as before described, *between their direct distances.* Thus, the vanishing line P D has a central distance expressing 35 degrees; the vanishing line N O a central distance expressing 25 degrees. Consequently, the original plane of P D makes with the original plane of N O 35° − 25°, or 10 degrees: being the angle R L D contained between L R and L D, the two direct distances.

A line then (the vanishing line of the plane of measure Art. 146) being drawn through the centre of the picture, joining the centres of any two vanishing lines: the angle made by their two original planes with each other is obtained by the *sum or difference* of the degrees marked at their central distances.

2. Measurement of this angle when the vanishing lines are *not* parallel.

(149.) That in every remaining case for ascertaining or representing the angle made by one original plane with another, the vanishing line of the plane of measure no longer passes, as in the above three examples, (Art. 148,) through the centre of the picture; but (the point being once determined where the vanishing lines of the two intersecting planes meet) a third vanishing line is found, as will be seen in Prob. VIII., to which all lines drawn from that point shall represent perpendiculars. This third line is the vanishing line of the plane of measure. (Art. 182.)

(150.) That the vanishing line of the plane of measure being graduated according to Case III. will express, at the points where it is crossed by the two vanishing lines of two intersecting planes, the angle of their inclination to each other.

3. Measurement when one of the two planes has no vanishing line.

(151.) That when only one of two intersecting planes has a vanishing line, the angle made by the planes with each other is the same angle made by that one plane with the plane of the picture.

Angles made by planes with the picture how measured.

(152.) That to find the angle made by any plane with the plane of the picture, observe the number of degrees marked on the central distance of its vanishing line. The complement of that number to 90°, is the angle sought. It is, universally, the *angle contained between the central and the direct distance.*

For example, perpendicular lines crossing the horizontal line in the points marked 10°, 20°, 30°, &c., (plate vii. fig. 2,) are the respective vanishing lines of planes which make the complements of those angles of 10°, 20°, 30° with the plane of the picture, and which have their *bases parallel to the station line.*

Also perpendicular lines crossing in like manner the station line in points marked 10°, 20°, 30°, &c., (plate vii. and x.) are, in like manner, the respective vanishing lines of planes which make the complements of those angles 10°, 20°, 30°, &c. with the perspective plane, but which have their *bases parallel to the horizontal line.* Thus the plane of which G I (plate x. fig. 1) is the vanishing line, makes an angle of 55° with the plane of the horizon, and makes, consequently, 35° the complement of 55, (*viz.* the angle C M L, or C M H,) with the plane of the picture.

In what circumstances two original planes must always be perpendicular to each other.

(153.) That all planes whatsoever, whatever be the direction of their bases or vanishing lines, are perpendicular to any plane of which the vanishing line contains their central distances. As examples to this rule, see Articles 124 and 125.

Vanishing point of all lines perpendicular to any inclined plane.

(154.) That when the graduations of any two central distances, situated in the same line, amount to 90 degrees: in other words, when any two direct distances are perpendicular to each other: their extreme points will be the centres of two remarkable vanishing lines. One extreme, or centre, will be the vanishing point of all perpendiculars to the plane of whose vanishing line the other extreme point is centre. (Art. 139.)

(155.) That when three original planes are perpendicular each to each, any one of the three becomes a plane of measure to the other two. For example, (plate vi. fig. 2,)

The plane	A	measures the angle made by the plane	B	with the plane	C.
	B		A		C.
	C		A		B.

The above rules recapitulated and exemplified.

A recapitulation may here be useful, and a reference, such as was given in Art. 34, to a general explanatory figure. (Plate vi. fig. 3.)

C the centre of the picture; C F principal distance; C D and C A central distances; D F and F A direct distances.

$q k$. Vanishing line of the planes of $l u$ and $y r$, making with the picture the angle C D F. (Art. 152.)

$h j$. Vanishing line of the plane of y &, making with the picture the angle C a F. (Art. 152.)

W C F
$h a j$ } parallel vanishing lines. (Art. 143, 147, 148.)
$q d k$

$y o$. Intersection of two planes y & and $y r$, both inclined to the picture. It is parallel to their vanishing lines W F and $q k$. (Art. 143.)

$s t$. Intersection of the plane $t n$, perpendicular to the picture, cutting the plane $t u$. It is parallel to their vanishing lines W F and $q k$. (Art. 143.)

$c o$. Intersection of a plane parallel to the picture cutting the plane $y r$. It is parallel to $q k$, the vanishing line of $y r$. (Art. 142.)

$a b$. Vanishing line of a plane, as $e g$, perpendicular to the picture, and also perpendicular to all planes whose vanishing lines, like hj and qk, cross ab at right angles: ab is here the vanishing line of the plane of measure. (Art. 127, 144, 146.)

ip. Intersection of the planes y& and eg. It vanishes at a, the point where the two vanishing lines meet. (Art. 145.)

wz and im. Intersections of two parallel planes sv and yr with the plane eg. Each intersection vanishes at D where ab meets and crosses qk. (*Ibid.*)

wx. Intersection of the plane tn with the plane eg. It vanishes at the point C where their two vanishing lines ab and W F meet. (Art. 141, 2.; and 145.)

pim. Representation of the angle made by the two planes y& and yr (both inclined to the picture) with each other. It represents the original angle contained between the two direct distances of their respective vanishing lines, *viz.* the angle a F D graduated on the vanishing line ab of the plane of measure. (Art. 93, 108, 143.)

xwz. Representation of the angle made by the plane tn (perpendicular to the picture) with the plane sv inclined to the picture. It represents the original angle contained between the direct and the principal distance, *viz.* the angle C F D as graduated on ab. (*Ibid.*)

PROBLEM VI.

rob. VI.

To prepare the perspective plane for Case III. viz. the case of planes inclined to the plane of the picture.

(156.) Hitherto our outlines have extended to the delineation of but a very few changes and peculiarities in the appearance of objects. We have considered indeed, and have exemplified at large, some useful methods of drawing varieties of form as they would appear to the eye, (like partitions upon a map, or like the lines of a chessboard,) on original plane surfaces; but our inquiry has been limited to only a small part even of these: as 1. *to such planes as directly face the spectator, and are parallel to his circle of vision*; 2. *to such planes as make right angles with the plane of that circle.* We now come, thirdly, to a division of our subject by far the fullest and most satisfactory; which ought to include every remaining requisite for perspective; and which refers to every possible position of planes not remarked upon in our preceding inquiries.

It will have been observable how very sparingly, in our foregoing endeavours, we have touched upon the representation of solid figures; whereas this latter part of the subject contains all that connects the Art with the realities of Nature: and we need not say, without such a connection, how useless would be our labour. A solid, in our Article on GEOMETRY, book i. p. 313, is defined to be "a body comprised under three dimensions, length, breadth, and thickness." To delineate, therefore, "length and breadth" only, without "thickness," would be as unpardonable in the delineator, as it would be in the Geometrician to stop short in his calculations, at the measurement of superficies merely, without regard to solid cubic contents.

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II.

But our notice of solid figures has, of necessity, been confined. We could, as yet, do nothing more than represent correctly a cube or parallelopiped, of which two sides would be parallel (as in Case I.) to the picture or perspective plane; and the other four sides perpendicular (as in Case II.) to the picture. Opportunity now occurs for representing, in the sides of such figures, each pair of parallel planes as making a separate angle of inclination with the plane of the picture. Nor need the student confine his operations to *regular* solid figures. He will find, that he may pursue satisfactorily to any extent which his curiosity and his leisure may combine to encourage, and very much further than our limits would permit us either to lead or to follow him, this interesting study: and may ascertain with perfect truth and correctness, the representations of solid forms as well in the most complex, as in the most irregular of their combinations.

The subject admits a wide range, but the materials for it are limited to straight lines and plane surfaces.

(157.) In this, however, and in every application of perspective rules, it must always be understood that the *materials* for construction are straight lines and plane surfaces. The only solid figure that can be delineated without the intervention of straight lines is the sphere.* And, although it were much to be desired, for the convenience of artists, that some instrument equally manageable and simple with the common compasses were invented to expedite the process universally of curvilinear projection;† we must rest at present satisfied with regarding solids in general as bodies to be represented within any number (not less than four) of intersecting planes, whose intersections with each other at the edge of its visible surface, or "disk," to borrow a term from Astronomy, constitute the lines and boundaries comprising the object. A reference to our Plates on CRYSTALLOGRAPHY may show the propriety of this definition, and will exemplify to the eye of the reader a series of outlines under great diversities of configuration formed by the intersection of plane surfaces inclined at various angles (all of which are distinctly calculable) to each other. See also the Article BODIES (regular) of our Lexicon, and plate xv. *Miscellanies.*

Number of vanishing lines required for representing a solid figure.

(158.) An opportunity here occurs (before we undertake the immediate business of this problem) of remarking upon the number of vanishing lines which belong to the representation of any given rectilinear solid. It is equal to the number of plane sides contained by the solid body, in all instances where no two sides are parallel to each other, nor any one of the sides parallel to the picture. But in every other instance, whatever number of sides are parallel to each other will have but one vanishing line, (Art. 65,) and whatever number of sides are parallel to the picture must be left out of the calculation. (Art. 67.) Reckoning first, therefore, the number of sides in any solid; deduct from it the number of parallels to any side, and like-

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* Every section of a sphere made by a plane is a circle. See book ix. p. 362, of our Article on GEOMETRY. In delineating any sphere, a plane is to be conceived as passing through its centre parallel to the plane of the picture. The section so formed will be a great circle, of which any radius may be selected and used as a base, for the purpose of delineating in perspective any other similar section. And whatever radius may be so selected, is to be regarded as the base either of a plane whose vanishing line (according to Case II.) passes through the principal point as its centre: or passes (according to Case III.) through any other point as its centre. Thus may any required number of curves, representing *meridians*, or other great circles, be drawn.

† The number and multiplicity of curves, more particularly in the application of perspective to subjects of *Naval Architecture*, as well as to tracery and fretwork in ornamented buildings, and to the delineation of *annulets, volutes, cornices*, &c., not to mention the perspective projection of even the most ordinary forms in wheelwork, and in the curvatures of machinery generally, would provide useful matter for a separate treatise. The reader will find in our Lexicon, under the word DRAWING INSTRUMENTS, a notice of some mechanic helps for outline in perspective, which have proved highly creditable to the ingenuity, skill, and science of the inventors.

wise the number of sides parallel to the picture. The remainder will be the amount of vanishing lines required.

An example of the varieties of position and consequent changes of outline in a cube or parallelopiped.

(159.) The simplest construction is that of a regular six-sided figure, (a cube or parallelopiped,) of which two pair of sides are perpendicular to the picture, and the third pair parallel to it. (Art. 156.) For such a representation two vanishing lines only are required; (Art. 158;) and these cross each other at right angles (as we have seen in Case II.) at the centre of the picture. (See any one of the boxes in plate iii. fig. 1.)

In a solid of this form there are twelve edges or intersections (Art. 157) which complete its boundaries; and which, in the position here chosen, may be drawn with very little preparation or trouble. Four of them vanish in the centre of the picture, (Art. 145,) and the remaining eight are parallel to the two vanishing lines, four to each vanishing line. (Art. 142.) But change now the aspect of the cube or parallelopiped, and let one pair of sides vary ever so little from its position as a parallel to the plane of the picture: an entirely new arrangement must be made. Not only does the centre of one vanishing line change its place, and move out of the centre of the picture, but there is immediately required a third vanishing line for the pair of sides that had before been parallel to the picture. Of the twelve edges or intersections, only four remain parallel to the perspective plane, *viz.* (if we select for an example the box in plate ii. fig. 1) *i t*, *s o*, *v x*, and *q m*. Out of the remainder, four vanish at L, and four at H, exemplifying, in the planes they belong to, the second variety of Case III.

(160.) But a still further change may be made. As yet, only two pairs of the sides of the parallelopiped have been moved so as to make a change of angle with the plane of the picture. One pair of sides still remain perpendicular to the perspective plane, and therefore vanish as before, (according to Case II.,) in a line drawn through the principal point. Let now, then, this pair of sides also be moved into an inclined position: again, a general alteration of outline ensues throughout the figure. The number, indeed, of vanishing lines continues still the same; but the three vanishing lines no longer have their centres joined in one straight line. They now range themselves in a triangle; of which the three angles form three vanishing points (Art. 145) for the lines of intersection or edges of the figure. Thus (plate xi. fig. 1) the die, No. 4., has no longer, as at No. 3., the centres of its three vanishing lines, M, C, and P, in one line W P, but its trey-side, which vanished in M P, now vanishes in H P; its deuce-side, which vanished in P Q, (a perpendicular at P, to C P its central distance,) now vanishes in X P; and its ace-side alone retains its previous vanishing line H X. The remaining three sides of the cube, opposite and parallel to these three, of course vanish similarly to these. (Art. 65.) The outlines of the four dice in plate xi. may serve to elucidate and exemplify the changes described above. Other figures more complex than the parallelopiped might be here introduced, but we reserve them.

A graduation (to prepare for Case III.) of the central distances.

(161.) We now proceed to the preparation of the perspective plane requisite for Case III. Those lines, radii to the circle of vision, which, in Case II., we have shown to be vanishing lines of all planes perpendicular to the picture, are now required to perform another office; and to furnish materials for the respective central distances of all planes more or less inclined to the picture. (Art. 24, 25, 26, 126.) Thus C O, (plate i. fig. 2,) a portion of the radius of the circle D A B E Z Y, is the central distance of the vanishing line B O E, belonging to a plane that makes the angle of inclination X O C or P V S (fig. 3) with the plane of the picture: and C M, being a portion of another radius, is the central distance of D Z, belonging to a plane that makes the angle of inclination A M C or P L S with the picture.

In order, therefore, to obtain with facility the vanishing lines of planes inclined to the picture, it will be proper to graduate, as was done in Case II., the horizontal or the station line, or both. (See plate vii. fig. 2.) The interval between any one of these points of graduation and the centre of the picture, will be the central distance of any required vanishing line of planes inclined to the horizon or to the station plane; provided the intersection be parallel to the plane of the picture. (Art. 143.) If the inclined planes vanish in a line parallel to the horizon, their central distances will be found in the station line. If the inclined planes, on the other hand, vanish in lines parallel to the station line, their central distances will be found in the horizontal line. For example, the following (plate x. fig. 1) being the central distances of vanishing lines parallel to H L, are found in the *station* line, *viz.*

$$\left.\begin{array}{l} CD\\ CR\\ CQ\\ CM^{55}\\ CM^{70} \end{array}\right\}\text{central distance of}\left\{\begin{array}{l} PD\\ NO\\ QF\\ GI\\ BM^{70} \end{array}\right\}\begin{array}{l}\text{a vanishing line}\\ \text{parallel to HL,}\\ \text{the horizontal}\\ \text{line.}\end{array}$$

And on the other hand, C H, (plate ii. fig. 1,) the central distance of the vanishing line M K, (parallel to C W,) is found in the *horizontal* line H L. With many more examples, that the reader will find without difficulty. (Art. 127.)

Uses of this graduation.

(162.) Also observe, that the number of degrees marked on the central distance of any vanishing line in the circumstances just described will express the angle of the inclination of its plane to the horizontal or station plane. Thus the number 25° marked at R, (plate x. fig. 1,) the centre of the vanishing line N O, is the number of degrees by which the plane vanishing in N O is inclined to the horizontal plane vanishing in H L. The complement of 25° is 65° or the angle C R L; being the angle (Art. 152) of inclination to the picture. Again, at L, (plate v. fig. 2,) the centre of the vanishing line M L parallel to C P; the number 55° indicates the number of degrees by which the plane of *s i f a* is inclined to the station plane: whereas the complement of that angle, or P L C, (35°,) is the angle made by the plane of *s i f a* with the perspective plane. (Art. 152.)

(163.) It must likewise be noticed, that when two vanishing lines are parallel, and have the centre of the picture situated between them, the degrees on the central distance, or the *sum* of degrees marked on their two intervening central distances, will express the angle made by the two planes with each other. For example, (plate x. fig. 1,) the plane *o m n p*, inclined to the plane of the bottom of a cart, vanishes in the line Q F with a central distance of 40°. The plane of the bottom of the cart *h i p* vanishes in the line P D with a central distance of 35 degrees. Consequently, the plane *o m n p* makes with the bottom of the cart an angle 40 + 35, or an angle of 75 degrees. If, however, the two parallel vanishing lines lie on the same side of the centre of the picture, the angle made by their two planes with each other will be the *difference* between the degrees of their two central distances. Thus the plane of *m l k n* vanishes in the line G I with a central distance of 55°, and the plane of *o m n p* vanishes in Q F, as before said, with a central distance of 40°. And these vanishing lines Q F and G I are on the same side of the centre C. Consequently, the angle made by the plane vanishing in G I with the plane vanishing in Q F will be 55° — 40°, or an angle of 15 degrees.

raduation central stances; ow computed.

(164.) There will likewise be necessity, as in Case II., (Art. 88,) for occasionally finding various other central distances, besides those graduated on the horizontal and station lines. Every vanishing line passing through the centre of the picture is liable to be thus graduated. (Art. 126, 161.) On such occasions, let arches of a circle concentric with the circle of vision be drawn as in Art. 88, where C M (plate vii. fig. 1) is graduated similarly to C B or C S. Thus the central distance C B (plate x. fig. 1) will be that of the vanishing line of a plane making 30° with a plane vanishing in A C, and the graduation on C P may be made most conveniently by circles having the centre C and with radii taken from the horizontal or station lines C 5°, C 10°, C 20°, C 30°, &c.

raduation f vanishing lines.

(165.) A further preparation will be required for the vanishing lines of planes peculiar to Case III. They must be graduated by means of radials from the furthest extremity of the direct distance, which for that purpose will have been raised perpendicularly at their centres. (Art. 29, 128, 131.) For example, F G (plate i. fig. 4, No. 1.) is the vanishing line of a plane making with the picture the angle of inclination C D R. At D its centre, where it is met by C D, its central distance, raise, on either side, (see note to Art. 29,) D H perpendicular to it, equal to D R, (Art. 25,) the direct distance: or continue C D from D towards C till it equals D R. Next from H, its furthest extremity, draw other radials H F, H G, &c. making the angles at H by which the line F G is to be graduated, and marking them on each side from the point D as from zero, in the same manner as was done in plate vii. fig. 1 and 2. The vanishing line V M (plate v. fig. 2) is thus graduated. Also the vanishing lines E B, (plate x. fig. 1,) S D, G I, K I, &c. are thus graduated.

tersecting original planes.

(166.) Under this preparatory problem it will be convenient and not inapposite to introduce a general view of the construction necessary for determining the inclination of original intersecting planes (Art. 16) to each other. *The intersection of any two lines is a point. That of any two planes is a straight line.* A slight acquaintance with the geometry of solids would here enable our student to recall the definition as given by Simpson, Playfair, or Bonnycastle, of the "angle made by two planes which cut one another," called by the former "the inclination of a plane to a plane." It is defined to be "the angle contained by two straight lines drawn from any the same point of the intersection of the planes, and drawn perpendicular to that intersection, the one in the one plane, and the other in the other. Of the two adjacent angles made by two lines drawn in this manner that which is *acute* is called the inclination of the planes to one another."

nclination of a ne to a ne" defined.

(167.) It is with a view of practically determining in all cases this angle of inclination, that we would proceed by means of a plane, which we have denominated the plane of measure. (Art. 146.) It is a plane in all cases perpendicular to the line of intersection of any two planes. It bears resemblance to what in Carpentry is termed a "bracket." The most indifferent mechanist must well know that a bracket rightly adjusted for fitting a corner contains an angle exactly equal to that of the inclination of the two planes which form the corner, and will be perpendicular to their line of intersection at some point in that corner.

How to measure and to represent their angle of inclination to each other.

Three aspects of their line of intersection.

There are three different aspects of the line of intersection made by any two planes:

1. It may be *parallel*
2. It may be *perpendicular* } to the perspective plane.
3. It may be *inclined*

1. Where it is *parallel:* either the vanishing lines of the intersecting planes are parallel to each other, or one of the planes has no vanishing line, *i. e.* is parallel to the plane of the picture. In these circumstances, the plane of measure must be perpendicular to the picture. The vanishing line of the plane of measure will consequently (Art. 65) pass through the centre of the picture and be perpendicular to the vanishing line of either intersecting plane. The vanishing line, thus found, of the plane of measure, and graduated according to Case II., (Art 82, 88,) expresses the angle made by the two original planes with each other, (Art. 163,) as has already been exemplified.

2. Where the intersection is *perpendicular* to the picture the intersecting planes must also be perpendicular to it. (Art. 141, No. 2.) Consequently, the plane of measure is in such a case the perspective plane itself; and the angle contained between the two vanishing lines meeting at the centre of the picture is the actual angle made by the two original planes, to which they belong, with each other. Here the original angle and its representation are one and the same. For example, the plane of the circle *z m i k s* (plate ii. fig. 2) is the plane of measure for the angles *z n m, m n i, i n k, k n s,* &c., and is perpendicular to the common intersection of eight planes, *viz.* to *n o*, vanishing in the centre C of the picture. (Art. 145.) The representation of these angles, therefore, belongs to Case I., and the construction of them resembles that of those in the triangles O P R, X N Q, &c. (Plate v. fig. 1, Art. 46.)

3. Where the intersection is *inclined* to the plane of the picture, the vanishing lines of the intersecting planes will meet at a point which is the vanishing point of their line of intersection. (Art. 145.) A future problem (Art. 182) will show the process of finding the vanishing line of a plane to which all lines vanishing in this point are perpendicular. That plane will be the plane of measure: and its vanishing line, graduated as above directed, (Art. 82, 88,) will show and express in its graduations (along the interval between the points where it is cut by the two other vanishing lines) the angle made by the two intersecting planes with each other. Thus the plane of the circle *a b d e f g* (plate ii. fig. 3) is a plane of measure. It measures the angles *a u b, b u d, e u f, f u g,* &c. because it is perpendicular (Art. 166) to the planes that make those angles. Its vanishing line is Y Z, on which the two lines forming any one of those angles will be found to vanish. It here measures the angle made by any two of four intersecting planes with each other. Their four vanishing lines meet at P, the vanishing point of *u* P, their common line of intersection, (Art. 145,) which is inclined to the plane of the picture. Out of

these four let us choose for examples two intersecting planes; the plane of $d r h$ vanishing in the line P Y; and the plane of $a r f$ vanishing in P Z. The vanishing line of the former cuts the vanishing line of the plane of measure in the point Y, which, if a graduation were completed on Y Z, would be marked 45°. The vanishing line of the latter cuts it at the point Z, which would be likewise marked 45°. In this manner 45° + 45°, or 90 degrees, would be found the original angle made by these two intersecting planes with each other.

Problem VII.

Prob. VII.

Given the vanishing line of a plane not perpendicular to the plane of the picture, to find the angles which any number of indefinite representations vanishing in that line make, either with the base of the plane to which they belong, or with each other; and to represent, as was done in Case II., any required portion of a line or angle belonging to a given plane. Also to represent, as was done in Case I., any point or line at a given distance from the spectator.

Inclination to the base found.

(168.) Let the given vanishing line be X M. (Plate iv. fig. 1.) If the indefinite representation be found to vanish in the centre D of X M, the angle made by it at the base has been already stated. (Art. 72.) Let it be required then to find the angle made by the indefinite representation t X with the base of the plane inclined to the picture, and vanishing in X M. Draw, parallel to X M through any point, as t, in the indefinite representation, the occasional base $t g$. Next, at the centre D (Art. 138) of the given vanishing line raise a perpendicular line equal to the direct distance. (Art. 27, 29, 131.) Join its furthest extremity R to the vanishing point X of the line t X. Lastly, to R X draw at the point t a parallel $t h$. The angle $g t h$ is the angle required. (Compare this with Art. 98.)

Inclination found with any other line in the same plane.

(169.) If for greater convenience the perpendicular D R be drawn on the other side towards C, the result will be the same: only the parallel $t g$ drawn through t will be on a different side of the line $t g$. In other words, the original angle will be on the same side of the base with its representation. (Compare this with Art. 99.)

(170.) Let it be required further to find the original of the angle $k t$ M made by the indefinite representation t X with another line whose representation $t e$ vanishes in the point M. To the same construction as above only add the line R M to join the furthest extremity of the perpendicular at D with the vanishing point of the new line. The angle X R M will be the original of the angle X t M, and will be expressed by the *sum* of the degrees at X and M, according to the graduation of the given vanishing line. (Art. 131.)

In like manner if $t s$ be the representation of a line making an angle with t X, let $t s$ be produced to its vanishing point q, and the *difference* of the graduation on D q from that on D X will express in degrees, minutes, &c. the angle sought.

To represent 1. A given angle; and in any required divisions.

(171.) Let it be next required to represent any angle, or any intended portion of an angle. This process is the converse of the preceding. Begin by constructing at t the intended original angle on the base $g t$. A parallel to $t h$ through R will cut X M in X, the vanishing point of the required representation. Then any original angle constructed at R with R X, such as X R q, X R M, &c., will give vanishing points, as q, M, &c., for the lines which contain the representation of that angle. (Art. 84.) (Compare this with Art. 108.)

2. A given line; and in any required divisions.

(172.) Another query of Prob. VII. is, how to represent a line of any given length. Find (Art. 56, 58, 99) the scale for the required representation, according to Case I., at the alleged distance of some point, as t, where the line in question crosses the occasional base. Mark off on the base, from the point t, the intended length, say $t g$. From X, measure on the side nearest D R, along the vanishing line, the interval X W equal to X R. Then from W (being the dividing point thus found, Art. 85) a line drawn to g will cut t X in the point K, and give the portion $t k$ for the representation of $t g$ required.

Here, as in the instance recently mentioned, (Art. 169,) it may often be convenient to erect D R on the other side in the direction of C.

The learner will have observed that all the above operations of Prob. VII. are perfectly analogous (Art. 131, 132, 133) to those of Prob. IV and V. (Art. 90 to 95; 98 to 102.)

(173.) A further analogy remains for our notice in the process of dividing, according to any given ratio, the representation $t k$.

Let it be required to divide $t k$, so as to represent three equal parts.* Trisect accordingly the portion $t g$, on the base. Lines from W, the dividing point, to the points of trisection will cut $t k$ in the corresponding points of representation. (Compare Art. 106.)

A similar observation here to one in Prob. V may be made. It is not always necessary to draw the base through the given point. Let the given point be z. A line from W through z will meet the base $t g$ in j. Then measured from j, let the portion required be $j g$. Draw W g as before. $z k$ will be the representation of $j g$. (Compare Art. 100.)

Similarity between this problem and Prob. IV and V.

Also we may find it useful to remark, that each of the methods of working introduced in Case II., besides the one we have thought proper to select, will be found available in the present problem. For instance, let the angle $g t h$ be constructed at t on the base by means of a parallel to R X drawn through t. A line R h will cut off from t X the representation required, namely, the portion $t k$. (Art. 102.) See also the other analogous modes of operation. (Art. 101, 103 to 106, and 113.)

Similarity between this and Prob. II.

(174.) Respecting the last particular required in this problem, namely, *to represent at a given distance from the spectator any point or line in the given plane;* we need only remark, that the operation is exactly similar to that which in Prob. II. has been described and exemplified at large. If in fig. 1, plate v. the point C be no longer viewed as the centre of the picture, but be reckoned as the centre of some vanishing line under Case III., the same methods of calculation, the same forms of construction, the same adaptation of scales originating in the measurement (Art. 56, 57, 58) of the principal distance, and set off on bases in the plane of the

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* The converse of this may be thus stated. Given any divided representation, as $t k$, to find the original ratio of the parts to the whole original line. For this purpose find the dividing point W; from whence lines drawn to the base through the representative divisions of $t k$ will give $t j$, $t g$, &c. and show the original proportions. This is a serviceable proposition (supposing a picture completed) for estimating the comparative magnitude of objects delineated, and for ascertaining their approach in this respect to nature, probability, and reality.

picture, will be found available. To show, however, the perfect accordance of the operation under Case III. with that under Case I.: let E G (plate iii. fig. 1) be some portion of the base or occasional base of a plain vanishing in H L, the horizontal line. Let E G be also an equal portion (Art. 33) of the base or occasional base of a plane, of whose vanishing line W is the centre. Draw E W and G W, E C and G C. It is evident that the parallels to E G, terminated by the lines vanishing at C and W, will express all the possible apparent lengths of E G upon either plane, at any distance from the spectator. (Art. 77.) To E G draw parallels at I, B, and A. It will be seen that E G, at the distance of the bottom of the box, is reduced in its apparent length to *x a*; which is equal to and in the same plane with (parallel to the picture) the parallel line at I. A little further off, at the back of the box, E G is reduced to *y* &; which is equal to and in the same plane with (parallel to the picture) the parallel line at B. Further off still, E G is reduced to *u t*; which is equal to and in the same plane with (parallel to the picture) the parallel line at A. The proportions, therefore, of E G, will be represented at the distances of *u*, *y*, and *x*, in the plane E *t*, (inclined to the picture,) after the same method as in the plane A G (perpendicular to the picture) they are represented at the points A, B, and I, of equal distance with *u*, *y*, and *x*.

(175.) It seems almost too obvious to be added, that in cases where the point W is not easily accessible, the proportions of such lines as *u t*, *y* &, and *x a*, may be found by perpendiculars from each extremity of the parallels at A, B, and I. These perpendicular lines will cut the indefinite representation E W in the points *x*, *y*, and *u*; and the indefinite representation G W in the points *t*, &, and *a*; thus obtaining *u t*, *y* &, and *x a*, for the proportions required.

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Prob.
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Bases
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(176.) To give some examples in the three varieties of Case III. The plane *a* V *b*, (plate iii. fig. 1,) vanishing in V R, has its base *a b* or *d h* parallel to the horizontal line. The representation *a d*, therefore, in that plane, showing the side of a square, is obtained by a line through *h* from the dividing point R, (Art. 133,) cutting *a* V (which, representing a perpendicular to the base, vanishes in V, Art. 72) in the point *a*. Or, if *a b* be used as a base, raise a perpendicular at *a*, equal to *a b*, and another at V equal to the direct distance. (Art. 128.) The line joining their furthest extremities will cut *a* V in the point *d*, and give *a d* for the required side of the square. Another example is presented in the figure of a double cross. (Plate x. fig. 1, No. 3.) Its upper and under surfaces (whose bases are parallel to the horizontal line) are in planes, which being inclined 70 degrees to the plane of the picture, and therefore 20 degrees to the plane of the horizon, (Art. 152,) vanish in a line drawn through U^{20} parallel to the horizontal line. Its right-hand and left-hand surfaces are situated in planes parallel to the station plane, and therefore belong to Case II., being perpendicular to the picture. They vanish in the station line. Their base *j k* is accordingly drawn parallel to their vanishing line. (Art. 64.) Its other surfaces being inclined 20 degrees to the plane of the picture, and therefore 70 degrees to the horizon, vanish in a line B M, through M^{70} parallel to the horizontal line. The plane of the bottom of the cart (No. 1.) has also its base parallel to H L. This plane is inclined 55 degrees to the picture, and therefore 35 degrees to the horizon and its vanishing line. Accordingly, P D passes perpendicularly through the point D 35 on the station line. (Art. 152.) The planes of *h g f i* and of *m l k n* also have their bases parallel to H L. The former of these planes being inclined 35° to the picture, and therefore 55° to the horizon, vanishes in G I, drawn through M^{35}. The latter making, with the picture and with the horizon, the same degrees of inclination as the former, vanishes of course in the same line G I.

2. Bases parallel to the station line.

Of the second variety of Case III., an example will be seen (plate ii. fig. 1) in lines representing two sides of a box, *viz. t i q m*, and *o s v x*, together with the two corresponding sides of the lid at *i e* and *s u*, belonging to two parallel planes. Both planes vanish in the line M H K, (Art. 65,) parallel to the station line. Likewise the vanishing line A M, (plate iv. fig. 1,) in which vanishes the plane of *a s o x*, containing the lines S M and *s* A; and the plane of *b e i f*, containing the lines *t* M and *e* A, is parallel to the station line. Again, in plate viii. fig. 1, the plane of each front piece, as A of the staircase, will vanish in a line parallel to the station line. The representations, therefore, of the perpendiculars to each base, will vanish in the several centres (Art. 72) of the 36 vanishing lines that cross the horizontal line at right angles in the points X, XX, XXX, &c. (Art. 152, 153.) It will be seen, however, that two of the 36 planes vanish in the station line, and consequently the treatment of them belongs to Case II.

3. Bases neither parallel to the horizontal nor to the station line.

For the third variety of Case III., examples are given in plates ii., iv., v., and x. The vanishing line M L (plate ii. fig. 1) of the plane on which is represented the square of the lid *i e u s*, is, as will be immediately evident upon inspection, neither parallel to H L nor to C W. Again, in plate iv. fig. 1, the vanishing line X M of the plane of the square *k t e s* is of the same description. To obtain the side *e t*, take a portion *e* N of the base equal to *l b* or *b c*. Next mark off from the point M on the vanishing line, the interval M Y equal to M R. From the dividing point Y thus found, a line through N will cut *t* M in *t*. Otherwise a diagonal drawn from *q* (the point of intersection made by R *q* in bisecting (Art. 117) the angle M R X) will give the point *t*. It will be seen that there may be cut off from *t* M, as was done from *t* X, any number of portions bearing any given ratio to each other. Lines from Y to the divisions N, n^2, n^3, on the base, will give the representation *t e*, *e r*, and *r p*, of this division. In plate v. fig. 2, the vanishing line V M being that of the plane of *h k w i*, expresses in its graduations the angle made by *i h* with *i w*, *viz.* $36° + 54° = 90°$. Here the representation *i w* is found (in the same way as heretofore exemplified) by the portion of a base, as *i n*, equal to the apparent length of *a z* according to its appropriate scale at the distance of the point *f*. Lastly, in plate x. fig. 1, No. 2. a representation of the line *s* T or *s* W, (being the proportionate length, from stem to stern, of the frigate,) is required to be cut off from the line representing an indefinite perpendicular *s* B to the base. The operation is the same as hitherto; either that of raising the direct distance a perpendicular at B; or of marking off the interval measured from the right or left of B for a dividing point. A line to T from the furthest extremity of the perpendicular, or to W from the point marked 45° (Art. 134) on the vanishing line E B, will give *s* V to represent the length of the vessel.

Observe also, in another part of the field of vision, the representation of the wheels of a cart. The planes of each wheel are not parallel to one another, and must therefore be represented with separate vanishing lines.

To one of them belongs D S, the vanishing line of the near wheel. The other vanishing line D S^2, with S^2 for its centre, in the direction of D F, is the vanishing line of the off-wheel. On the felloe, or circumference of the latter, one circle will be observed to vanish in the plane of the spectator's eye, and therefore must exhibit the appearance of a straight line. (Art. 137.)

Mechanism of wheel-carriages affords examples for this variety of Case III.

(177.) Respecting the former, although it would, in a view of the real object, be entirely concealed by the side and body of the vehicle, we have nevertheless introduced an outline of it for the sake of one or two somewhat trite observations, but necessary to our purpose. In the construction of wheel-carriages, it is a well-known principle, for the sake of safe conveyance, in cases where the unevenness of the ground throws the weight on one side, and consequently on the wheel or wheels attached to that side, so to arrange the spokes, as that each of them in its turn, when its outer extremity reaches the ground, should become a sufficient prop and support. The superincumbent weight would lose its balance, and would overturn the whole, if this prop or spoke were not placed sufficiently under it, outside of the line of gravitation, as far as conveniently may be practicable; a precaution not necessary towards the inside, or space between the wheels, because the weight on that side is shared by the other wheel. The precautionary contrivance for the aforenamed purpose is both effectual and simple. The direction of the spokes in converging from the periphery to the axis, instead of being perpendicular to the line of the axle-tree, is so managed, that each of them, on coming to the ground, may make outwards, a more or less acute angle with the line of axis; the better to sustain and balance the load above, whenever, from the inequalities of the road, or from whatever cause, it leans upon one side. In short, the axis is that of a cone formed by the revolution of the spokes, the apex of which cone lies in the nave or centre-piece of each wheel.

Our outline in plate x. fig. 1, No. 1. will perhaps be more intelligible by reason of the above remark. The twelve points in the circumference of the wheel are obtained in a very similar manner to those for the 12 lamps in Prob. V. The parallels on each side of X Z have their representations vanishing in S, the centre of the vanishing line of the off-wheel. (Compare Art. 113, 114, and 115, with Art. 128, 129.) From these points thus obtained, lines must be drawn to some point in the axis, (at the distance sometimes of a foot from the linch-pin,) for the top of the cone above described. These lines (see the dotted lines in the figure) represent the position of the twelve spokes. The eye of the draughtsman will also quickly perceive that, besides the inclination of the spokes, tending, as was remarked, to equilibrium and steady conveyance, the axis also of each wheel is made to favour the same object, by having a certain degree of inclination downwards; and the wheel is made broad with two, and sometimes three iron plates or felloes, one beside the other, forming the frustum of a cone, with the same axis as that of the spokes, but tapering outwards in an opposite direction, and with its apex at a distance of some yards.

Further helps adapted both to Cases II. and III. for the projection of circles in perspective.

(178.) This may be a proper place to introduce some helps generally applicable in both Cases II. and III. to the representation of circles, or arcs of circles, and contributing as well to accuracy as facility of execution. The following method requires no more than a fourth part, or quadrant, to be drawn at the base. Having chosen some point, as *v*, (plate x. fig. 1, No. 1.) in the perspective plane for the centre of your representation, draw through that point the representation of a perpendicular to the base. It will vanish at the centre S of the vanishing line. (Art. 72.) Produce it in the opposite direction to meet an occasional base at Z, sufficiently distant from *v*, to admit room for the construction. Raise at Z a perpendicular on the side furthest from S. From the furthest extremity Δ of the perpendicular at S, (which, in the present case, equals the direct distance,) draw through *v*, a line cutting Z X in X. X will be the point for the right angle of a quadrant one side of which, X Z, is perpendicular to the base.

Let it now be required to give the representation *r w b a* of the arc Z Y. For this purpose, suppose Z Y divided into any number of equal parts, say three. The lines X 3 and X 6 forming those divisions, will cut the base at the points 3 and 6. Draw lines, through *v*, from these points. Also draw through *v*, a parallel *a u* to the base. Thus will be represented the three intended angles trisecting the quadrant, *viz.*

$$\left.\begin{array}{r} ZX3 \\ 3X6 \\ 6XY \end{array}\right\} \text{represented by} \left\{\begin{array}{l} Zv3. \\ 3\ v\ 6. \\ 6\ v\ 9. \end{array}\right.$$

Extreme nicety and minuteness attainable if required.

(179.) If, for the sake of minuter accuracy, a greater number of divisions be called for in the arc Z Y; suppose it divided, as the quadrant at B, (plate v. fig. 2,) into nine parts, each of which will, of course, be 10 degrees. Lines, it will be seen, here again must be drawn cutting the base at the points 1, 2, 3, 4, 5, 6, &c. If still greater detail be desired, which in large works, in scene-painting, for example, may be occasionally necessary; let a quadrant be drawn of any magnitude having the same centre, B or X, (plate x.) as the other, and having one side perpendicular, as B Q, (plate v. fig. 2,) to the base at O. On the arc Q D, thus constructed, it is evident that any number of degrees, minutes, or seconds may be distinctly defined: and that lines, drawn to B, from the graduations on the arc, (as those of ten degrees between 40 and 50,) will cut the base in the manner here shown, on the interval between numbers 4 and 5, in corresponding graduations. This done, the operator needs only proceed as has been directed.

Usual method of working when a li cannot be drawn of sufficient length.

(180.) Frequently, however, it happens that there is want of room, that the base is very limited, that it either is inaccessible, or has been continued to the utmost margin of the work, and cannot contain further graduations. This difficulty is easily surmounted. Join by a line, X *v*, (plate x. fig. 1, No. 1.) the centre of the original to the centre of the representation. Draw to this line any where without the arc X Y a parallel, as *q* 9, crossing the base at B. Make *q* B and B *m* together equal to the interval X *v*, between the centres *v* and X; that is, make *q* B equal to X *e*, and make B *m* equal to *e v*. Finally, join *q m*. We are now prepared for the difficulty mentioned. Suppose even every other part of the base inaccessible, and it be required to represent indefinitely the line X *q*, forming the angle Z X *q*. Make B 9 equal to B *m*. The representation 9 *u* drawn through *v*, will give the angle 9 *v* Z to represent the angle *q* X Z.

Suppose further, a given number of divisions of the angle 6 X *q* be required. Let the lines, as X q^8, X q^7, forming those divisions, be produced to meet *q* B 9. Through the points 9^8 and 9^7 draw parallels to *m q*.

Observe the points *m*^{8} and *m*^{7}, where those parallels cut the base. Next, cut off from B 9, a portion B 7 equal to B *m*^{7}, and another portion B 8, equal to B *m*^{8}. Lastly, from the points 7 and 8, lines through *v* will give the representations 9 *v* 8, 8 *v* 7, and 7 *v* 6, of the three angles contained in 6 X *q*. A similar proceeding appears in plate v. fig. 2. It will be of use to the learner to trace the resemblance. A line B O indefinitely represented by O D; W B drawn through C and B to determine the two centres: *l c* and *c m* two radii parallel to the base: *r n* parallel to and equal to F B. Y *r* equal to F C: *k x* parallel to *n* Y: *r a* made equal to *r x:* and lastly, *a c* drawn through *c* from *a*, making the representation *a c m* of the angle *k* B 9. The graduations on the vanishing line contribute much to the accuracy of the work. From the point marked 1, for instance, on the base, an indefinite representation is drawn to 10° on the vanishing line. From 2 another to the vanishing point marked 20°. From 3, a third to that marked 30°, &c. all passing through *c*. The base points to the left of O or of Z (plate v. or x.) being determined as above; those to the right, O 1, O 2, O 3, O 4, &c. or Z 3, Z 6, &c. are easily obtained by merely transferring these intervals along the base, from one side of the perpendicular O B or Z X to the other.

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(181.) We have only as yet found certain angles at the centre of the circle. Its circumference remains to be accounted for. In this part of the process we are to consider our perspective representation of a circle as that of a regular polygon, approaching nearer to the form of a circle the greater the number of its sides. Let us conceive this polygon divided into equal and similar triangles, (one triangle for each side,) of which the angles we have just been representing (Art. 180) are situated at the vertices. The angle at the vertex in any one triangle subtracted from 180°, leaves for remainder the amount of the angles adjacent to its remaining side at the circumference of the circle. Halve this amount, and we have the angle made by each side of the polygon with the adjacent radius. Thus, let *u v a* (plate x. fig. 1, No. 1.) be fixed upon for the diameter of the projected circle. Draw lines in the quadrant Z Y joining the points of its trisection. These lines complete three triangles, each of which at its vertex X contains an angle of 30 degrees. $\frac{180 - 30}{2} = 75$ degrees, *viz.* the amount of the angle made by each side of the hexagon with its adjacent radius. The radius *b v* representing with the base (or with *a v*) an angle of 30° will vanish at the point marked 60. (Art. 94.) Reckoning therefore from 60° as from zero (Art. 111) along the vanishing line, we perceive that a line to make 75° with *b v* must vanish at the point marked 15° beyond the centre S. From the point therefore marked 15 on the vanishing line D S towards Q let a dividing line be drawn through *a*. It will cut the representation 6 *v* in *b*. Again, the line *w v* vanishes at the point marked 30. A line, therefore, to represent 75° with *w v* must vanish at the point marked 45°. From 45° accordingly, a dividing line through *b* will cut 3 *v* in *w*. Thirdly, the line Z *v* vanishes in S, the centre of the vanishing line. A line therefore representing 75° with it, will vanish at the point marked 75°, from whence a dividing line through *w* will cut Z *v* in *r*. But the extremity *r*, as well as &, its opposite, will be always best obtained by a dividing line through *a*, or *u*, from the point marked 45° on either side of the centres of the vanishing line.* (Art. 134.)

Suppose then our quadrant *a b w r* to be a satisfactory projection of Z Y. Lines representing perpendiculars to the base, (or to *a u*,) and drawn accordingly to S from the points *b* and *w*, will cut 3 *t* 30 in *s*, and 6 *j* 60 in *d*. And parallels to the base (or to *a u*) from *b* and *w*, will again cut the same lines in *t* and *j*; thus leaving a fourth part only of the representation to be completed. This completion will be performed either by parallels to the base through *d* and *s*, or by representations of perpendiculars to it (or to *a u*) drawn through *t* and *j*.

PROBLEM VIII.

Prob. VIII.

Given on the perspective plane any point; to find a vanishing line from which all lines drawn to that point shall represent perpendiculars to whatever plane vanishes in that line. Also given any vanishing line; to find the angle made by the plane it belongs to, either with the picture, or with any other plane, whether that other plane be parallel to the picture, or have a given vanishing line.

Vanishing line found of the plane of measure.

(182.) Let C (plate xi. fig. 1) be the centre of the picture, and P the given point. Join P C, and at C raise to C P a perpendicular C D equal to the principal distance. At D construct upon D P the right angle P D M, and produce P C to meet D M at M. In other words, find a third proportional C M (Art. 139) which shall be to C D as C D is to C P. A perpendicular through M to M P will be the vanishing line required. M will be its centre, (Art. 75, 138,) and M C its central distance. (Art. 24, 25, 26.)

Corollary.

(183.) *Cor.* It is evident that if the point M had been given instead of the point P, that the foregoing operation would have procured P for the centre, and C P for the central distance of the required vanishing line of a plane, to which all lines drawn from the point M would represent perpendiculars. (Art. 139.)

Angles found of inclination made by original planes with the picture.

(184.) To perform the next part of the problem, a certain property of the given vanishing line must be ascertained. If the given vanishing line pass through the centre of the picture, (Art. 34,) the angle which the plane it belongs to makes with the picture, has, throughout the whole of Case II., been already stated.

But if the given vanishing line pass through any other point as its centre, let B (plate x. fig. 1, No. 2.)

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* An isosceles triangle of this kind with 10° at its vertex, must have 85° for each of its other angles. Consequently, any line, to represent an angle of 85° with the line *a c* (plate v. fig. 2) vanishing at 80°, must vanish at 5° on that side of D nearest to M, and the other dividing points will be found in the following order:

A line to make 85° with another line vanishing at	70°	must vanish at the point marked	15°.
	60		25.
	50		35.
	40		45.
	30		55.
	20		65.
	10		75.

If this sort of calculation be considered tedious, there is always the alternative, whenever the perpendicular at D, as D W, (plate v. fig. 1,) or at S, as S △, (plate x. fig. 1, No. 1.) namely, the principal, or, as the case may be, direct distance, is accessible; of drawing lines to such points as R W V A, &c., in the original arc below the base, which lines will cut the several indefinite representations in corresponding points, *r*, *w*, *b*, *a*, &c. (Art. 99, 100, 113.)

be that centre, and E B the given line. It is required to find the angle of inclination made with the plane of the picture by the plane vanishing in E B. Having found C B the central distance, (Art. 138,) raise at C on either side of C B a perpendicular A C equal to the principal distance. Complete the triangle (Art. 25) by joining A B. This will be the hypothenuse or direct distance drawn from the extreme point of the central to the extreme point of the principal distance. The angle A B C will be the angle required, namely, the angle of inclination made with the plane of the picture by any plane vanishing in E B. (Art. 152.) It is always to be found at the centre of the vanishing line. It is here 60°, being the complement to 30°, the angle marked on the central distance at B.

(185.) The examples are numerous in which this operation may be repeated throughout the three varieties of Case III. It has been thought convenient to collect them in the subjoined Table, placing them in the order of the plates, and leaving the practitioner to class the different planes for himself according to the direction of their bases or vanishing lines.

Examples.

Plate.	Fig.							
ii.	1.	Given the centre	E	of the vanishing line,	M L	to find the angle of inclination made to the picture by the plane of	*i e u s*	and its parallels.
......			H		M K		*i q m t*	
......			L				*q v x m*	
iii.	1.		V		V R		*d a b h*	
......			W				E *u t* G	
......			Z				*d n l h*	
iv.	1.		D		X M		*s k t e*	
......			X		F E		*a s e b*	
......			V		A M		*b e i f*	
......					X A		*s* A *e*	
v.	2.		D		V M		*h k w i*	
......			V				*e x s a*	
......			L		M L		*a s i f*	
vi.	3.		*a*		*h j*		*y* &	
......			D		*q k*		*u s t v*	
vii.	1.		30		F I		*r p c*	
x.	1. No.1.		D		P D		*o h i p*	
......			Q		Q F		*o m n p*	
......			S^2		S^2 D		the wheel at *l*,	
......					G D		*f k n*	
......					D I		*g l m*	
......	No. 2.		K^{80}		K^{80} I		*b d*	

Angles found when made by any two intersecting original planes with each other.

(186.) Lastly, it is required in Prob. VIII. to ascertain the *angle made with each other by any two original intersecting planes* of which one vanishing line at least is given. We include here right angles as well as angles of inclination, or *acute* angles. (Art. 166.) There are four divisions under which may be classed all pairs of intersecting planes, *viz.*

1. Any two planes, *one of which* being a plane under Case I., *has no vanishing line.*

2. Any two planes with *vanishing lines* (and, consequently, bases, Art. 64) *parallel* to each other.

3. Any two planes with *vanishing lines perpendicular* to each other, and one or both of them passing through the centre of the picture.

4. Any two planes with vanishing lines that *meet and intersect in all other ways.*

Four classes of intersecting original planes. 1. The first class.

(187.) 1. Respecting the first mentioned of these classes the rule has been already given, (Art. 151,) that the angle made by one plane with the other is the same as that made by one plane with the plane of the picture. Consult for practical illustration,

Plate.	Fig.						
iii.	1.	where the plane	*d a b h*	makes with the plane of the picture and with the plane	*e d h g*	the same angle, viz.	C V L
......			*e m f g*		*e d h g*		90°
......			*g h i f*		*e d h g*		90°
......			*d n l h*		*e d h g*		C Z L
......			*j p r k*		*p o s r*		90°
v.	1.		*g i t h*		*g a f h*		90°
vi.	3.		*y r*		*c o*		C D F
ix.	5.		*s i t e*		*s w*		90°.

2. The second class.

(188.) 2. Respecting the second class of these intersecting planes it has been stated (Art. 148) that the sum or difference of the angles marked on the central distances of their two vanishing lines will express the angle required; namely, the angle contained between their two direct distances; or in case one only of them has a central distance, then the angle expressed is between the direct distance of that one and the principal distance. We need only, therefore, refer to some examples for practice.

Pl.	Fig.								
ii.	1.	The given vanishing line of the plane of	*q v x m*	is parallel to the vanishing line	M K	of the plane	*t i q m*	and the angle found to be made by the planes with each other is	H W L
iii.	1.		*d n l h*		V R		*d a b h*		V L Z
....			*d n l h*		H L		*d z i h*		C L Z
....			E *u t* G		H L		A G		C L W
iv.	1.		*a s e b*		A M		*b e i f*		X P V
v.	2.		*e x s a*		M L		*a s i f*		V P L
vi.	3.		*y* &		*q k*		*y r*		*a* F D
....			*u s t v*		W F		*n t*		D F C
vii.	1.		*r p c*		B D		*r q*		C B 30
x.	1. No.2.		*s b h* V		A C		*s* C W		C A B
..	1. No.3.		*a g h b*		BM^{70}		*a b d e*		DHM^{70}

To which may be added the numerous examples in plate viii., where the plane of the front piece of each step makes an angle of ten degrees with that of the adjacent step: ten degrees being the difference between the central distances of their two vanishing lines; the vanishing lines, moreover, of all being parallel, and therefore of this class; and S C, their occasional base, common to all.

3. Third class of intersecting planes.

(189.) 3. Respecting the third class of intersecting original planes, it has been shown, that where one vanishing line contains the central distance of another, the two planes to which they belong will be perpendicular to each other. (Art. 153.)

(190.) And if neither of them have a central distance, *i. e.* if both of them pass through the centre of the picture, the two planes will make each with each the same angle as their respective vanishing lines do with each other. (Art. 147, 167, No. 2.) For illustration of this last particular, see plate vii. fig. 1, where B C O is the angle made by the plane *a l i b* with the station plane: and O C P the angle made by it with the horizon. Also in plate x. fig. 1, No. 2. B C D the angle made by the plane of the ship's keel with the station plane; and B C H the angle made by it with the horizon.

(191.) And for examples of cases where one vanishing line contains the central distance of another, see the plane *r p c* (plate vii. fig. 1) of a window shutter. It is perpendicular to the horizon, since its central distance C 30 is contained in the horizontal line. Also see plate x., where all the front pieces of the steps are perpendicular to the horizon, since the horizontal line contains all their central distances. See further as follows.

Plate. Fig.	The plane	is perpendicular to the plane	whose vanishing line contains the central distance
ii. 1.	$mtiq$	$toxm$	C H
....	$mqvx$	$toxm$	C L
.. 3.	bPg	ePj	C P
iii. 1.	$ubfx$	$ghif$	C Z
iv. 1.	$aseb$	$baxf$	C X
....	$beif$	$baxf$	C V
v. 2.	$aexs$	$aedf$	C V
....	$asif$	$aedf$	C L
vi. 3.	y &	eg	C a
....	yr	eg	C D
x. 1. No.3.	$aghb$	$bhid$	C U^{20}
....	$abcd$	$bhid$	C M^{70}.

Fourth
ss of in-
secting
nes.

(192.) 4. The fourth class, including every other kind of mutual intersection by two original planes, remains for our notice. Let, then, the two given vanishing lines be PH (plate xi. fig. 1) and PX, and let them be produced till they meet at P. It is required to find the original angle made by any plane vanishing in PH with another plane vanishing in PX. Having found the point P, next find the vanishing line, HX, (Prob. VII. Art. 182,) of all planes to which lines drawn from P will represent perpendiculars. Produce the two vanishing lines to meet HX at H and X. HX will be the vanishing line of the plane of measure. (Art 146, 182.) At M, its centre, raise MW, its direct distance, from the furthest extremity of which draw two lines to the points H and X. Between these two lines will be contained at W the original angle required, namely, the angle HWX made by any plane vanishing in HP, with any plane vanishing in XP. In like manner, if the vanishing line PM, or PA, be chosen for meeting HP at P, HWM, or HWA, will be the original angles of inclination sought; *viz.* HWM the inclination of any plane vanishing in HP with any plane vanishing in WP; and HWA the inclination of any plane likewise vanishing in HP with any plane vanishing in AP. A few examples may suffice. As in

Pl. Fig.			
ii. 1.	M L	is the vanishing line of the plane of measure to two intersecting planes that vanish in	K M and K L
iv. 1.	A M		X A .. X M
x. 1. No. 1.	G I		D G .. D I
.... No. 1.	G I		D S .. D S^2.

PROBLEM IX.

b. IX.

Given any vanishing point, and the angle made with the picture by any plane which contains the line vanishing in that point: to find the vanishing line of that plane; and to find the vanishing point of all lines perpendicular to that plane.

(193.) We have observed (note to Art. 145) that in order to determine any vanishing line, two points, at least, must be found or given within that line. In the present problem one of these two points within it is given. The other, which we must proceed to find, is that point within it called its centre. (Art. 71, 138.)

If the given point *be that centre itself* of the vanishing line, it is obvious that no further operation is necessary than to draw, through the given point, a perpendicular to the central distance; which perpendicular will be the vanishing line required. For example, let the given point be M, (plate xi. fig. 1,) the centre of the vanishing line HX. Nothing further is needed than a perpendicular to MC through M, in order to find that vanishing line.

Vanishing line found of a plane making with the picture a given angle.

(194.) But if the given point be some other, as A, *apart from the centre*, let any radius, as CK, be drawn to the circle of vision: and at its extremity (the extremity of the principal distance) let the complement of the given angle (Art. 152) be constructed, *viz.* at K. At C let a perpendicular be raised to KC; and let that perpendicular together with the leg of the angle at K be produced till they meet at I. CI will be the central distance of the required vanishing line. With CI, therefore, for radius, describe the arc IM, and from the given point A, draw the tangent AM, or AH, (see our *Treatise* on GEOMETRY, book iv. prob. xvi. p. 328,) which will be the required vanishing line; with $CM = CI$ for its central distance, and MD, or MW, for its direct distance. (Art. 26.)

(195.) Next, *to find the vanishing point of all lines perpendicular to a plane vanishing in any given line.* If the given vanishing line pass through the centre of the picture, the lines in question will have no vanishing point but will be parallel to the picture, and must be drawn perpendicular to the base. For example, mq, ti, os, and xv, (plate ii. fig. 1,) representing perpendiculars to a plane vanishing in HL, are drawn in a direction perpendicular to the base gz, since their originals are parallel to the picture. Other examples will be found everywhere in Case II.

Vanishing point found of all perpendiculars to a given plane.

(196.) But if the given vanishing line be out of the centre of the picture, as HX, (plate xi. fig. 1,) find its central distance CM. (Art. 138.) On either side of CM draw CD, or Cd, (the principal distance,) parallel to the given vanishing line. Make at D with MD a right angle, the leg of which produced will meet MC (also produced) at the point P. In other words, find CP, (a third proportional,) which shall be to CD as CD is to CM. (Art. 139.) P will be the point required. Had the point Q been the given point in any vanishing line of which P should be found to be centre, a similar operation to the foregoing would discover M as the vanishing point of all perpendiculars to any plane vanishing in PQ. (Art.154.)

Cor. 1.

(197.) *Cor.* 1. The line WP, if graduated as the vanishing line of a plane of measure, (Art. 146,) will contain the central distances; and will measure the angles made by any planes with each other whose vanishing lines cross it like HX and QP at right angles. (Art. 148, 153.)

Cor. 2.

(198.) *Cor.* 2. Should the centres only be given of the vanishing lines of two original planes; or should the angles only be given made by each plane with the plane of the picture, the angle made by the two original intersecting planes with each other may be found. For,

If the vanishing lines *are parallel* to each other, a line joining their centres will express the angle made with each other by the intersecting planes. Thus, (plate xi. fig. 1,) the graduation of MP expresses the angle made by the plane vanishing in HA with the plane vanishing in PQ. Or, find the central distances (Art. 148) by means of the angle each plane makes with the picture. And, on the other hand,

If the vanishing lines *intersect* each other, and the points B and E be their given centres: join BC and EC, to which, at the points B and E, raise perpendiculars HB and AE. These will be the vanishing lines required, and being produced, will meet at P. Then by Prob. VII. (Art. 182) find the vanishing line HX of the measuring plane. The angle H W A will be the angle made by the one intersecting plane with the other; or supposing only the angles given made by each original plane with the picture, find (Art. 148) their two central distances, and proceed as before.

Cor. 3.

(199.) *Cor.* 3. Given the two vanishing points of any two lines that meet each other; to find a third line which shall represent a perpendicular to both the former at the point where they meet.

Join the two vanishing points. The line so drawn is the vanishing line of a plane containing the given two lines. (Note to Art. 145.) If it pass through the centre of the picture, let fall a perpendicular to it from the point where they meet. This will be the perpendicular sought.

But if the vanishing line of the plane of the given two lines does not pass through the centre of the picture; find (Art. 195) the vanishing point of all perpendiculars to any plane vanishing in that line. From that point so found draw a straight line to the given point where the two lines meet. This will represent the required line perpendicular to them both. Thus to *c a* and *a b*, vanishing in the line N O, (plate x. fig. 1, No. 4.) a perpendicular will be represented by *a d*, a third line drawn from the point M[55].

Cor. 4.

(200.) *Cor.* 4. All lines perpendicular to any plane whose vanishing line passes through the principal point, are parallel to the plane of the picture.

For they have no vanishing point (Cor. 3. Art. 199) and must be therefore parallel to the perspective plane, as the planes are to which they belong. (Art. 67.)

PROBLEM X.

Prob. X.

Given the angle made by any two planes with each other, and the angle made by one of them with the plane of the picture, and given the vanishing point of their line of intersection; to find their respective vanishing lines. Also given the vanishing line of any plane; to find the vanishing lines of any number of planes perpendicular to it, and making any given angle with each other.

1. The two vanishing lines found when the line of intersection is *parallel* to the picture;

(201.) When the line of intersection is *parallel* to the perspective plane, and has therefore no vanishing point, the two vanishing lines of the two intersecting planes will be parallel to it, and to each other; (Art. 143;) and the angle made by the two planes with each other will determine, as already stated in the last problem, the interval between their vanishing lines, *viz.* their two central distances. (Art. 197.)

But should only one of these two intersecting planes have a vanishing line, the angle made by them with each other will determine, as stated in Problem VIII., (compare Art. 187 with Art. 142,) the position of the vanishing line parallel to the line of intersection.

2. Found when the intersection is *perpendicular* to the picture;

(202.) When the line of intersection is *perpendicular* to the perspective plane, the two intersecting planes are also perpendicular to the picture, and the angle made by them with each other will determine, as stated in Problem VIII., (Art. 189,) the direction of their vanishing lines.

(203.) If therefore in the present problem, the given vanishing point of the line of intersection be the centre of the picture, the two intersecting planes will belong to Case II., and the angle made by them with each other being also given, first draw one vanishing line in any required direction; and then construct upon it with the other, at the centre of the picture, the given angle.

3. Found when the intersection is *inclined* to the picture.

(204.) But let any *other point*, as P, (plate xi. fig. 1, No. 5.) *not in the centre of the picture*, be given for the vanishing point of the line of intersection. And let the given angle made by the two planes with each other be fifty-five degrees. Also let the angle made by one of them with the picture be an angle of forty-four degrees. It is required to find the vanishing lines of the two planes.

First find H X, the vanishing line of the planes to which all straight lines from P will represent perpendiculars. (Prob. VIII. Art. 182.) Next, find the central distance, (Prob. IX. Art. 197,) and the vanishing line (containing the given point P) of a plane that makes the given angle C F G of 44 degrees, with the plane of the picture. Produce this vanishing line, as P F, to meet that of the plane of measure at X, and having drawn W X from the extremity of the direct distance, construct at W the given angle made by the two intersecting planes. Let X W M be the given angle. Join M P. M P and X P will be the two vanishing lines required.

In the same manner, if the given angle made by the two planes with each other were X W A, the two vanishing lines would be found to be P X and P A; or, if the given angle were X W H, the two vanishing *lines* would be found to be P X and P H.

Vanishing lines found of any number of planes perpendicular to a given plane.

(205.) The last desideratum of Prob. X. is, *to find the vanishing line of any number of original planes perpendicular to some one original plane* of which the vanishing line is given.

Let the given vanishing line be H X. Find P, the vanishing point of all lines perpendicular to the plane vanishing in H X. (Prob. IX. Art. 196.) Through P draw any number of vanishing lines to meet H X. These will be the vanishing lines required; namely, the vanishing lines of planes, which, whatever be the angle made by any one of them with another, are all of them perpendicular to the plane of which H X is the vanishing line.

Angle found made by any two of these planes with each other.

And if the vanishing line H X be graduated, (Art. 165,) the several angles made by the perpendicular planes with each other will be expressed by those graduations. Thus the angle

made by the plane vanishing in the line	with the plane vanishing in the line	would be found to be
H P	M P	35°
H P	A P	35+35=70°
M P	A P	35
A P	X P	55−35=20°
M P	X P	55
H P	X P	35+55=90°

Cor. 1. Peculiarity in the three vanishing lines of a cube or parallelopiped.

(206.) *Cor.* 1. In the triangle H X P, let either of the three points H, X, or P (since each of the three is the vanishing point of all lines perpendicular to a plane vanishing in the side opposite to each) be chosen as a vanishing point of lines of intersection. The side opposite that chosen point is the vanishing line of the plane of measure to all planes whose vanishing lines pass through that point. Consequently, any vanishing lines passing through that chosen vanishing point of intersection will be vanishing lines of planes perpendicular to the plane of measure, or to any plane vanishing in the line of the opposite side of the triangle. This opposite side (being produced sufficiently at each extremity, and graduated according as it belongs to Case II. or III.) will always express any angle made by the perpendicular planes with each other.

.2. ther iliarity.

(207.) *Cor.* 2. Any one side, therefore, of the triangle just described, is the vanishing line of a plane of measure to all planes that vanish in the other two sides; (Art. 155;) and any one side contains the two vanishing points of all lines perpendicular to planes that vanish in either of the other sides. The side H X, for example, contains the vanishing points X and H; X that of all lines perpendicular to any plane vanishing in H P, and H the vanishing point of all lines perpendicular to any plane vanishing in X P. The same remark applies to the points X and P contained in the side X P, as well as to the points H and P contained in the side H P.

.3. resenta- found plane inter- s (in a n line, at a n an- another inal e.

(208.) *Cor.* 3. Given the representation of a portion of any plane, to represent another plane making with it a given angle, and passing through a given line of intersection.

Let the given intersection be the line *n s* (plate xi. fig. 1, No. 5.) drawn upon a portion of a plane vanishing in M P; and let it be required to represent a portion of another plane passing through *n s*, and making an angle of 55° with the former plane. Produce *n s* to its vanishing point P in the given vanishing line. Then find H X, the vanishing line of the plane of measure, (Prob. VIII.) and proceed as directed above. (Art. 205.) The result will be X P, the vanishing line of the new plane. Lines drawn through *s* and *n* to any point or points in the vanishing line X P will give a portion of the plane required.

4. esen- o found e angle e by inter- ng nal s with other.

(209.) *Cor.* 4. To represent by two straight lines drawn on the two intersecting planes the angle which they make with each other. Choose, in the line of intersection, any point, as *o*, and having found by the foregoing operations (Art. 205, 208) the points M and X in the vanishing line of the plane of measure; draw lines through the point *o* from M and X. The originals of these lines belong to the plane vanishing in H X, to which *o* P must always represent a perpendicular. Consequently, *o t* and *o r*, representing perpendiculars to the line *n s* of intersection, (Art. 166,) will contain the representation of the angle M W X, made by the intersecting planes with each other. Observe that the angle *t o u* represents an *obtuse* angle; therefore the angle of inclination must be expressed by its complement *t o r*, formed by *o r*, vanishing in M, and *o t* vanishing in X. A flag-staff shows the direction of lines perpendicular to each plane.

uding a- on per- e.

(210.) Examples in each of the three varieties of Case III. might have been subjoined to the two foregoing problems. But we have already much exceeded our intended limits with respect to this essential branch or rather root of the art; (see note to Art. 2;) and we may now fairly regard the learner as being enough a proficient to discover throughout the several plates, with which we have endeavoured to familiarize him, illustrations to his purpose.

It may suffice to explain, cursorily, some constructions of outline, given in plate x. fig. 1. To draw the ship, No. 2: first find E B, the vanishing line of the plane of its deck* perpendicular to B K^{∞}, (Art. 153,) the vanishing line of the plane of its keel,† which latter plane is here indefinitely represented by the triangle B *s* K^{∞}. Observe that the point B is the vanishing point of all lines of intersection (Art. 167, No. 3.) made by planes vanishing in E B and in B K^{∞}, *i. e.* of all lines extending, in nautical phrase, *fore and aft;* right ahead or astern. Also observe that the point K^{∞} is the vanishing point of the masts, and of all lines perpendicular to the deck; (Art. 195, 196;) and, on the other hand, B, the vanishing point of all lines perpendicular to planes vanishing in K I,* whose intersections with the plane of the deck extend from any given point starboard to its corresponding point on the larboard side, or *vice versâ.* These latter intersections will be parallel, in this example, to the perspective plane (Art. 195) and to the vanishing lines E B and K I of the two latter intersecting planes. (Art. 143, 148, No. 2. and Art. 167, No. 1.)

(211.) Draw parallel to E B, the base *a* W. At B raise perpendicularly the direct distance. (Art. 130.) Make *s* T or *s* W equal to the length from stem to stern. Having completed the three plans, (see notes to Art. 210,) make *s z* equal to *s* Z^2 for the place of the deck; draw *z* B, representing the intersection of the plane of the deck with that of the keel, and find in *z* B the points *f*, *g*, and *i*, representing F, G, and I, the centres of the mizen, main, and fore masts. Proceed next, by lines crossing the deck, parallels to *a* W, or to *s* T, (if parallels to *s* T they must vanish at B,) to find, in the same manner as in the representation of a circle, (Art. 114,) the several points for the upper tier of guns. For the lower tier, mark off from *s* T, *s* M equal to *s* M^2. A line M B will cut G K^{∞} in *m;* and *m e* (for the lower tier) will represent half the breadth at the main-mast or midship, as *f d* (for the upper tier) does at the mizen. From *d* and *e* draw to K^{∞} I lines representing with the perpendiculars to the deck an angle of twelve degrees. This will show what is termed the *canting* of the ship's side; as will also a line from *c* to K^{∞} I, representing an inclination of five degrees in a similar direction for the upper-deck ports.† Lastly, *s* N being made equal to *s* N^2, will give *n* n^2 representing, at the midship or main frame, the greatest breadth of the vessel. Observe that the line *s* 30°, drawn from *s* to the vanishing line B K^{∞}, shows the centre of the vanishing line of the plane of the ship's stern. This line contains the vanishing points for the sides of the windows, &c.

(212.) To draw the masts. Erect for a base at *a* or *s*, a perpendicular to *a* W, or rather a parallel to B K^{∞}. Draw also to the point K^{∞} the indefinite representation of a parallel to the mast, which is here taken to be a perpendicular to the plane of the deck.‡ Let *a* X be the required occasional base, and *a* Y (vanishing at K^{∞}) the representation of a parallel to the mast. Draw *a* B, and through the points *f*, *g*, and *i*, in *s* B, draw the representations *o* K^{∞}, *p* K^{∞}, and *q* K^{∞}. To begin with the proportions of the mizen-mast: mark them off on *a* X, according to the scale of the plans, No. 2., and having

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* Called, in ship-building, the *half breadth*, or *floor* plan, or *horizontal* plane. The last of these terms implies a vessel *on the stocks*. Our example, plate x., is of a vessel in a storm at sea.

† Called the *sheer*-plan, or plan of *elevation*, being a vertical plane passing through the keel.

* The *body* plan, or *plane of projection*, is a section of the ship at the mid-ship frame, or broadest place, perpendicular to the two former. From these three plans, the necessity is manifest of constant attention to the three particulars, namely, length, breadth, and depth, or thickness, (Art. 156, 157, to 161,) essentially combined with all solid forms.

† Those timbers whose planes are perpendicular to the sheer plan are called *square* timbers, and those whose planes are inclined to it are called canted timbers.

‡ Whatever deviation from this perpendicular may be required by the naval architect might be expressed with the same accuracy; (Prob. V.;) but the small size of our diagram makes the difference quite immaterial.

found the dividing point of a Y, (Art. 133,) transfer to a Y the divisions of a X. Draw $b\,c$ (a parallel to a W) through the line of the mizen-mast. At b, b O vanishing in K^{80} represents a parallel to a Y. From the divisions therefore on a Y, draw lines to B (Art. 77) cutting b O in the points O and r, through which O o and r R, two parallels to $b\,c$, will give o for the place of the cap, and R for the place of the round top. Proceed in the same manner for the main and fore masts, and indeed for all lines in planes parallel to the plane of the keel.

To draw the bowsprit. Let V k and $a\,y$ vanishing in the line B K^{80} represent the angle made by the bowsprit with the base a X, just as a Y represented the angle so made by the masts. Mark off on a X the required proportions, which will be transferred to $a\,y$ by means of its dividing point. (Art. 133.) Next, a parallel through V to a W will give the point h; through which $h\,j$, vanishing in the same point with and similarly divided with $a\,y$, (Art. 77,) will give the point j for the cap of the bowsprit. Lastly transfer the point j to k, by a parallel $j\,k$ to a W.

(213.) A representation is given (plate x. fig. 1, No. 4.) of a double cross formed of seven cubes. The vanishing lines and points for the cube in the centre are manifestly the same as for the surrounding six. None of the three pairs of parallel sides is parallel to the perspective plane; and their three vanishing lines form a triangle, (Art. 160,) two points of which are in the line N O, marked 40° and 50°, and the third at 65°, in the vanishing line D C M.

No. 5. is the representation of an octahedron, or eight-sided figure, formed by two pyramids having a common base. It is a regular solid, contained under eight equilateral triangles, whose intersections are the sides of the three squares $a\,b\,c\,d$, $d\,e\,b\,f$, and $a\,e\,c\,f$. These squares intersect each other in their respective diagonals, ($e\,f$, $a\,c$, and $d\,b$) (Prob. X. Cor. 3.) and each of the squares is a common base to two pyramids.

No. 6. represents a six-sided figure, formed also of equilateral triangles. It shows a method by which is found the vanishing line of the base of a pyramid whose six sides are equilateral triangles; one of the six (*viz.* the side $g\,\sigma\,h$) being parallel to the perspective plane. At the point L (C L being the principal distance) make $t\,l\,r$ an angle of 60°, or $r\,l\,w$ an angle of 30°. Find the perpendicular $d\,r$ to the base of the equilateral triangle t L r, and cut off L s equal to it. Then with $s\,m$ (equal to $t\,r$) and L m (equal to L s) construct the triangle (isosceles) L $m\,s$, and produce m L to U. U L is the direct distance, C U the central distance, and U the centre of the required vanishing line; and the triangle $\sigma\,\lambda\,\mu$ will represent the original s L m, *viz.*

$$\left.\begin{array}{r}\text{The angle } m\,\mathrm{L}\,s\\ \mathrm{L}\,m\,s\\ \mathrm{L}\,s\,m\end{array}\right\}\text{will be represented by}\left\{\begin{array}{l}\mu\,\lambda\,\sigma.\\ \lambda\,\mu\,\sigma.\\ \lambda\,\sigma\,\mu.\end{array}\right.$$

The line $\sigma\,M^{70}$, or $\sigma\,p$, passing through the apices of the two pyramids, is found by bisecting the base $g\,h$, and drawing from λ to the dividing point of $h\,\mu$ a line cutting $h\,\mu$ in o. (Art. 118.) Next, to the point o draw the representation $g\,o$ of a perpendicular to $\mu\,h$. A line $s\,p$, or $\sigma\,M^{70'}$, drawn through the point where $\lambda\,\mu$ cuts $o\,g$, will be the line required, representing a perpendicular to the plane of $g\,\mu\,h$ at its centre. Or the vanishing point of $\sigma\,p$ may be found by Problem IX. (Art. 196.) Observe, that for the four sides of the upper pyramid $g\,\mu\,\sigma\,h$, there are but three vanishing lines, (Art. 158,) since one side is parallel to the picture. Also the vanishing line of $\mu\,g\,h$ will be a parallel to $g\,h$ at U, (or a perpendicular to U C,) and the other two vanishing lines will be parallels to the bases (Art. 64) $g\,\sigma$ and $\sigma\,h$, cutting the vanishing line at U in the points where it is met by $g\,\mu$ and $h\,\mu$.

For the four sides of the lower pyramid there will be four vanishing lines. One, the perpendicular to R C at U, just stated; another parallel to it at the vanishing point of $\lambda\,p$, for the vanishing line of the plane of $p\,g\,h$; and the remaining two crossing the two former in the vanishing points of the lines $g\,\mu$, $h\,\mu$, $g\,p$, $h\,p$.

No. 7. is a dodecahedron, or twelve-sided figure, formed of two pyramids, whose common base (a hexagon) vanishes in P D. The perpendicular $a\,b$, at the centre of the common base, will be found to vanish in the point marked M^{35}. (Prob. IX. Art. 196.) There will be twelve vanishing lines to this figure. To find these, observe that the figure is formed by the boundaries of three equal and similar rhomboids intersecting each other in three lines or diameters, which cross the centre of the hexagon. The vanishing line of the plane of each rhomboid must be drawn from $M^{35\circ}$ (the common vanishing point of their line of intersection $a\,b$) to certain points determinable in P D, the vanishing line of their plane of measure. (Art. 146. See also Prob. X.)

No. 8. is another dodecahedron formed of twelve rhomboids, for the planes of which (since each has its parallel) there must be six vanishing lines. (Art. 158.) The plane of the uppermost vanishes in the line P D.

(214.) That the course of study we are here advocating cannot be prosecuted without considerable pains and unremitting efforts will be obvious. But ***nulla dies sine lineâ*** must be the Painter's motto. To every mind that prefers certainty to guesswork; to every understanding that cannot be satisfied without a clear and good reason for its mode of pursuing any object; to every imagination that has enough vigour and soundness to despise unqualified applause, and aspire only to judicious praise; we need not urge the necessity of clearness, nor the advantage as well as gratification of obtaining truth. We admit that it is very possible to acquire great correctness of outline, and yet make no acquaintance in any degree with either perspective or anatomy.* By accustoming the eye to measure intervals of distance, and the hand and pencil to nice divisions of lines, as well straight as curved; by observing narrowly throughout the objects to be copied, what points lie above or below each other in a vertical direction; and what points lie on the same level in horizontal lines; and then by transferring carefully these points to the drawing board, or canvass, previously to filling up the intermediate parts; a considerable knowledge may be obtained of the true forms of objects, as well as of their just delineation. We are far from wishing to supersede these useful exercises. On the contrary, we would particularly recommend the mere beginner to practise making outlines of regular figures, such as the triangle, the circle, the square, the parallelogram, the rectangle, and regular polygons in general. Let him

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* There is a degree of popular wonderment, often fatal to scientific progress in any Art, excited by the exclamation, How surprising! and yet he *never learned to draw!* or, How marvellous! what an ear! she *does not know a note of music!*

Other mechanical helps might be named. But our object here is not to dwell upon expedients by which the rules of Perspective are supposed to be superseded. Our meaning is to assure all who trust implicitly to such expedients, that without acquaintance, practically, at least, with this interesting branch of Geometry, no helps from even the completest mechanism will avail. The slightest accident may cause, in any instrument hitherto constructed for this purpose, a woful deviation from Truth and Nature. To correct these deviations is the business of Perspective; and to give the artist such well-placed confidence in his representation of outline, as will encourage him to finish his performance without fear of being reduced to the shame and trouble of subsequent attempts (when they may be too late) at alteration of his work.

(217.) Thus far we have proceeded in this elementary department, in these introductory rudiments as they only claim to be called, of the Grammar of Painting. For, indeed, a knowledge, however perfect, of Perspective, is to Art, no more than what a perfect knowledge of orthography or of pronunciation is to Language. No very great credit in the exercise of written or spoken Language attaches, among educated persons, to the individual who spells or who pronounces it with correctness; and yet to spell or to pronounce incorrectly, is held disgraceful. So also, merely to draw with accuracy ought not to satisfy the aspiring artist. His outlines, to claim conspicuous merit, must have force and meaning as well as truth; while at the same time he should regard and avoid false Perspective, with as much alarm and abhorrence as is manifested by the rhythmical scholar towards a *false quantity!* There is a difference too in their origin, between the language of the Painter and that of the Etymologist, which acts, or ought to act, upon the mind of the former as a continual incentive to superior caution, and more jealous observance of elementary rules. The laws of outline are deduced from daily and universal experience.* They appeal to facts which every eye, almost instinctively, can attest; whereas the laws of speech are conventional and arbitrary. To all attempts, therefore, of the careless draughtsman to find apology for deficiencies in Perspective by appealing to like examples of deficiency in the Golden Age of Art among its ablest professors, we answer that those great authorities would, in a later Age, have been most keenly sensitive to criticism in these respects. They would be the first to perceive, that in the natural progress of Taste commensurate with the spread of general knowledge, inattention to the rudimental particulars in question leads as effectually to weaken, or destroy, the intended impression of a fine Picture; as the delivery, in a broad provincial accent, of even the most brilliant Speech in Shakspeare would be insufferable to polished ears, and would be found to mar and murder all its eloquence and beauty.

Of Outline.

Of Anatomy.

Its connection with Perspective in Painting.

(218.) We would next direct the student's attention to some acquaintance with Anatomy. While pursuing this important study, he must not imagine that Perspective may be laid aside.* On the contrary every step in that initiatory path leads to proficiency in this more advanced stage. As well might a Grammarian (to repeat the above figurative allusion) discard the most essential letters of his alphabet, and pretend to form a Language without vowels, as an artist expect, without the practice of foreshortening whatever object, animate or inanimate, may be submitted to his pencil, to obtain even the lowest grade of professional mediocrity. Perspective is, as we have seen, the *Art of foreshortening.* The rules of it have been applied, in the preceding examples, to objects possessing neither vegetable nor animal life; to works of human contrivance in Mechanics and in Architecture. We must now apply it to the representation of natural phenomena. And of these we begin with animal forms, as having more obvious regularity of outline.† Outline of landscape and of the scenery of Nature will follow next in order. After which some necessary observations on outline as connected with character and expression will then conclude this division of our subject.

(219.) The study, indeed, of Anatomy for the purposes of Painting, has in view two objects, which we take leave to distinguish by the terms Configuration and Expression.

1. The first of these is introductory to the second. It consists in such a knowledge of the several parts of the animal figure as can represent each part in its proper form and place, and can preserve at the same time the

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trivance is described by Mr. R. L. Edgeworth as the invention of Miss Maria Edgeworth. Another Delineator of easy construction, is a fixed upright frame, across which a number of very fine threads or wires are stretched, crossing each other at right angles, and dividing the frame into a number of small squares. The paper on which the drawing is made is also ruled with a like number of squares. Looking through a fixed sight at a little distance from the frame (answering to the principal distance, Art. 9, 10) the operator observes on what square the object he wishes to represent is found, and draws the object in the corresponding square upon the paper. At the end of Brooke Taylor's *Perspective* (edition of Kirby, 4to. 1768) is described an instrument to the same purpose formed by two rulers, horizontal and vertical; the former fixed, the latter sliding in a groove upon it. Both are numbered in equal divisions that correspond to a certain number of ruled squares on the drawing. The operator looking, as before, through a fixed sight adjusts the vertical ruler to any point in an object, and then comparing the graduation on the rulers with that on the sides of his drawing-board, he transfers each point so found on his *perspective plane* to its corresponding place on his paper, just as he would compare, in copying a map, the points of longitude and latitude, and find by their means the relative position of any given spot, town, or mountain.

* *L'Anatomie et la Perspective sont des Sciences exactes; elles s'appuyent sur des démonstrations: elles ont pour objet des vérités démontrées. Lorsque dans les écoles et dans l'opinion publique, ces Sciences ne seront plus considérées comme fondemens indispensables de la Peinture, on pourra prononcer hardiment que cet Art et les parties qui en dépendent sont menacés d'une prochaine décadence.* Watelet, *Encyclopédie Méthodique. Beaux Arts.*

* The necessity for combining Perspective with Anatomy arises from the general regularity of animal forms. If there were no symmetry in the human frame: if, for instance, the right side did not assimilate with the left, Perspective might be less important, and the figure of a man might be drawn as much *ad libitum* as that of a tree or a mountain. Mengs, who is a strong pictorial authority, has these words in a Treatise on Art at the end of his Works. *Para dibuxar bien las estatuas es necessario saber la perspettiva.*—To draw well from the antique, a knowledge of perspective is indispensable. *Obras de* Mengs, p. 334. *en* 4to. Madrid, 1780.

† We would recommend the student to make frequent drawings of such machines, more or less complicated, as he may have opportunity of examining either in motion or at rest. This practice gives accuracy to his eye and hand, and prepares him for delineations of a higher order in *animal* mechanics. He will afterwards be better able to appreciate in his mind, and to represent with his pencil, the most perfect state to which he can possibly conceive the means and powers of locomotion and of machinery (if the works of Divine wisdom may so be termed) to be advanced. And indeed, to all who desire practical and endless evidences of the immeasurable interval between the contrivances of Man and the works of Him who gave life, and mind, and soul to the contriver, we would recommend, previously to anatomical inquiries, as much acquaintance as their leisure will permit with the best mechanical efforts of human ingenuity.

several proportions of any one limb or feature compared with any other.[*] To this preparatory knowledge belongs a vocabulary of the principal bones and muscles; the outline and position of the former in a state of rest; together with the shapes, origin, and insertion of the latter. And as the state of animal rest seems included specially under this head of the subject, we shall here have opportunity of allusion to the natural arrangement proper and necessary for balancing the animal in any required posture. We here also may remark particularly upon the agency of such muscles as are partly involuntary, *i. e.* in some degree independent of the will. Under this head it will suffice to describe the *position* of the voluntary muscles, or those under the influence of volition.

2.. The second object and ultimate aim of the student is Expression, of which, however, under the head Composition, we shall say more in its more appropriate place. Expression regards the use and active application of the materials before enumerated. As in the Art of Navigation it is one thing to know the names, form, position, and relative magnitude of the decks and timbers; of the masts and yards, blocks, sails, and rigging; and quite another kind of knowledge to apply all these organs of motion to their respective uses: so in Anatomy the study of action follows that of mere configuration. And this study of Anatomical expression involves, with every artist, considerations that demand consummate judgment, taste, and skill. Here comes his ordeal. Here he gains that point at which the stride of genius begins, and from which a chaste and vigorous imagination springs, like a giant, into an arena suited to its powers, leaving far behind it the laborious insipidity of less gifted, unobservant, and uninventive minds. Here, in short, lies the especial province of the artist: namely, out of infinitely varied forms to make a happy choice of such peculiarities in look or gesture as are best adapted to convey, through the magic of sympathy, certain passions or sentiments of the mind, or to indicate certain propensities of the will. All the *voluntary* muscles are, in attaining this latter object, called alternately into play, for which in a state of rest he only had before acquired the nomenclature.

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ating.

We have taken the more pains in drawing the above distinction in order to justify to our readers the enlarged sense in which, by the term Anatomy, we wish to be understood. We do not limit this word, as has been often done in Treatises on Art, to the study of the human subject alone. We consider that an acquaintance with the forms of animated nature, generally, is essential to the student. He will be well rewarded by devoting close attention to those forms. Not only he will find that every animal has a *character* analogous to the lines of his pencil in depicting it; but also that he will be enabled to represent with more elevation and dignity, the noblest of living shapes, the frame of Man, in proportion as he abstracts it from mere animality and appropriates to it features, and signs and movements purely intellectual. In order to do this, the artist must be familiar with those peculiarities of inferior animal expression which, wherever they appear, as in nature they are for ever doing, degrade and brutify the human subject. He must know what to reject, before he can turn to use what it is proper to retain.[*]

(220.) But we must not be tempted to enter further upon this interesting portion of our task until we have attended duly, as was proposed, to the *configuration* of animals.

Animal structure divided into three regions.

In order to avoid confusing himself among the multitude of parts essential to life and motion, we advise the learner to examine, separately, certain larger masses or districts of the animal body, so that he afterwards may mark with greater distinctness and fidelity their relative position, and the union of the whole when in their natural state of action or of rest. These portions seem very conveniently reducible to three: 1. the *region of the Head;* 2. the *region of the Thorax*, or chest; 3. the *region of the Abdomen;* all terminating at a common boundary called the spine or back bone, the respective divisions of which into *cervical*, *dorsal*, and *lumbar vertebræ*, serve to indicate, in each species of animal, the extent of each region. Consequently, in that of the head we include the bones and muscles of the neck; in that of the thorax, the arm of the human subject, the wings and forelegs of birds and brutes; in that of the abdomen, the legs of the biped, and hinder legs of quadruped animals. It will be useful also for the student, under each of the above-named three districts of the body, to divide his observations into,

1. Such peculiarities of the bones as are essential to marking the outward form.

2. Imaginary points, lines, and planes, for deter-

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[*] *L'Anatomie demande lorsqu'on veut s'en instruire, qu'on étudie, qu'on observe, qu'on médite, dans les plus grands détails, tout ce qui compose l'organization des êtres vivans. Cependant, son object principal est l'organization de l'homme, comme la plus intéressante, relativement à nous. L'étude de l'Anatomie doit aussi s'étendre sur l'organization des animaux: s'occuper, pour s'éclairer davantage, des rapprochemens et des comparaisons du méchanisme des animaux et de celui de l'homme. Il ne s'agit pas pour le peintre de se plonger dans cette immense entreprise. L'artiste ne s'occupe, en général, que de l'extérieur.* Watelet, *loc. cit.*

[*] The Work of Mr. Charles Bell on *Anatomy of Expression* is or should be familiar to every English artist. Like Camper, who preceded him on a similar subject, this author joins the advantage of considerable ability as a draughtsman to professional skill as an Anatomist. Remarking that the Grecian Sculptors were evidently intimate with Comparative Anatomy, he thus quotes from Winklemann. *Pour peu qu'on examine la configuration du roi des Dieux, on découvre dans les têtes toute la forme du lion, le roi des animaux; non seulement à les grands yeux ronds, à son front haut et imposant, et à son nez, mais encore à sa chevelure, qui descend du haut de la tête, puis remonte du côté du front et se partage en retombant en arc: ce qui n'est pas le caractère de la chevelure de l'homme, mais celui de la crinière du lion. Quant à Hercule les proportions de sa tête ou cou nous offrent la forme d'un taureau indomptable. Pour indiquer dans ce héros une vigueur, et une puissance supérieure aux forces humaines, on lui a donné la tête et le cou de cet animal; parties toutautrement proportionnées que dans l'homme, qui a la tête plus grosse, et le cou plus mince.* Œuvres, p. 367, 368. "I would refer," says Mr. Bell, "the peculiarity of the beautiful and impressive form of the antique head to this principle, that the ancient artists sedulously avoided whatever was deemed characteristic of the brute, and magnified those dimensions of the human countenance which mark the distinguishing attributes of Man. The Principle of composition among the Ancients is worthy of our study: they soon left mere imitation, and advanced to a higher study, that of ideal form, in which they endeavoured to combine excellences, and to avoid whatever might tend to injure the design or to impair its effect. And in this pursuit they seem to have studied, with peculiar care, the forms and expression of animals as contrasted with those of mankind. We trace this method of study in many pieces of antiquity where the artist has endeavoured to convey the character of dignity, or bodily strength, or courage, by transfusing into his composition some of the peculiar forms of animals, as in the personification of Gods and Heroes. We may trace it also in ancient Masks, Satyrs, Fawns, and Centaurs, where it was the artist's design to brutify the countenance; a peculiarly ludicrous effect is produced by the union of brutal physiognomy with human expression." Some Treatises by this author on *Animal Mechanics*, published by the Society for the Diffusion of Useful Knowledge, we particularly recommend to students in Art.

mining the relative position of the bones, as seen from any point of view.

3. The motions of which the bones in each region are capable.

4. Such muscles as are visible instruments of motion.

The remarks which our limits permit under each of the regions mentioned, will, accordingly, invite attention to those four particulars.

Region of the head. Its bones.

(221.) 1. THE REGION OF THE HEAD. To begin with the *bones*. For the names, forms, and articulation of these we refer the reader to our pages on Anatomy and Osteology, as well comparative as confined exclusively to the human body. We here only remark, and the remark applies to outline of animals generally, that, for the purposes of Painting, all those prominences which are but thinly coated with muscular or tendinous fibre, require to be most minutely examined, to be carefully borne in mind, and to be continually copied in various lights, and under every point of view consistent with their appearances in the living subject. Such as, in the human skull: 1. The two protuberances on the forehead, conspicuous in all adult subjects, and arising from the enlargement of the frontal sinuses. 2. The temporal ridge of the os frontis, on each side of the forehead, extending externally upwards from the orbital arch towards the temples.[*] 3. The ossa nasi, giving form to the bridge of the nose.[†] 4. The orbits or sockets for the eyeballs,[‡] and more particularly the zygomatic process of the cheek bone. 5. The zygoma, or jugal arch, formed by the uniting processes of the cheek and temporal bones. 6. The mastoid processes. 7. The occiput, and the points immediately behind the foramen magnum.[§] 8. The foramina of the ear. 9. The lower jaw. Its several motions upward, downward, and lateral, round the centre of the glenoid cavity. Its angle and the length of its two sides[*] forming that angle. In infancy its angle obtuse, and its alveolar extremity comparatively short. In manhood its angle approaching to a right angle, and its alveolar process nearly on a vertical line with that of the upper jaw. In old age its angle again obtuse, with a remarkable protrusion of the chin from loss of teeth. 10. The interval between the outermost of the six front teeth, or rather between the two foremost of the molares, an interval which determines the width of the mouth and breadth of the chin.[†] 11. Respecting the seven bones of the neck, there seems occasion to notice only the peculiar way in which the first or uppermost, termed the *atlas*, encloses and turns upon the second, termed the *dentata*.

Method of Camper, by imaginary lines.

(222.) The next concern of the artist is, to devise *certain imaginary points, lines*, or *planes*, by which he may most readily complete his outline, or correct it when completed. Professor Camper, in the Work which we have already had occasion to quote, has given a method which appears sufficiently accurate, and very practicable for outline of the human head, and which he proposes to substitute for the method in his time (he died in 1789) commonly received. "All writers on the principles of Drawing," he observes, (in page 109 of the translated Work,) "propose the oval, as the best method of obtaining a sure hand in sketching heads in every position, and of every age. No one has ventured to deviate from the method, notwithstanding every one must have been convinced, from experience, that this figure is frequently defective, and merely applicable in a few instances." The author then proceeds to show, that the oval form commonly received, although useful for finding certain points in the full face, is not applicable for determining the features correctly in any other position. The oval which he conceives to be a good one, and "well adapted to all those cases where it can be applied with advantage," he describes as follows:

"Let the height A B (see a copy of his diagram in plate iii. fig. 6) be divided into four equal parts, A H, H I, I F, F B; of these take three-fourths, or A F, equal to K L, for the largest dimensions, and describe the circle A K F L. The ears are to be placed between the parallel lines K L and M N. Divide K L into four equal parts, and take one-fourth for the breadth O I and I P," (between the temples and the top of the nose.) "Extending the compasses from F to I, or to the half of A B, draw from the point F, in the centre line A B, the circle B N I M. Complete the oval from K to M and L to N. Finally, divide A B into four equal parts, of which one is destined for the nose; and B F into three, of which the uppermost gives the seat of the upper lip Q R."

(223.) In other parts of his Work this ingenious and

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[*] "Two kinds of structure are observed in the horned pecora. These are either proper horns, as in the genera of the ox, goat, and antelope, or bony productions, as in the genus *Cervus*, which includes animals of the deer kind. In the former genera, the external table of the frontal bones is elongated into one or more processes: in the greater number the frontal sinuses extend into the horny processes. In the stag (in the male only in most genera) the frontal bone forms a short, flattened prominence, from which the proper antler immediately shoots." Blumenbach's *Manual*, Lawrence's edition, 8vo. Lond. 1827, p. 22.

[†] The varieties of individual form in the space between the inner corners of the eyes, are infinite. Notwithstanding the smallness of the ossa nasi in the human subject, they constitute a feature so strongly characteristic as to require the most careful study. The integuments which cover them are so closely fitted as to show every the most minute indentation. By the Portrait-painter, who must aim especially at *likeness*, the peculiarities of the nasal bones, as well in their projection from the face as in their junction with the upper maxilla and orbital arch, cannot be examined too particularly. On this see Da Vinci, *Trattato della Pittura*, cap. 187. 189. These bones in quadrupeds are yet more remarkable. The Roman nose in a horse is a very distinguishing feature.

[‡] Of the two corners of the eye, the inner one is always the more prominent; consequently, if two straight lines be drawn, one through the corners of each eye, the lines will meet and form an angle somewhere opposite the junction of the ossa nasi. For the Perspective of the face, the lines forming this angle require especial attention. In most birds, and in all timid or watchful animals, the hare, the cat, the horse, &c., this angle is proportionably acute, and the outer corner of the eye retires so much as to admit, not only of looking sideways, but, in some degree, even of retrospective vision.

[§] The parts here numbered 6 and 7 are not important so much for their form, as on account of the muscles thereto attached. For, as in order to draw any line, straight or curved, with precision, the points must be first clearly decided where to begin, and where to end; so in delineating the muscles, the draughtsman must previously assure himself where they originate, and to what point or points they tend.

[*] See Dr. Cogan's translation of Camper, 4to. Lond. 1794. In page 67, the progressive changes are remarked in the growth of the upper and lower jaws. In page 72, the effects of age are noticed on these features. See also Blumenbach in the Work before quoted, p. 24. sec. 23.

[†] "The size of the mouth is in proportion to the distance of (interval between) the dentes canini, or eye-teeth, in men and animals, with only a few exceptions. Or, to speak more properly, the angles terminate at the commencement of the first double tooth or grinder. Many animals have not the eye-teeth. In apes therefore, in the orang, and in the negro, the rim or angle of the mouth must be more distended than in a European, as the projection of the upper jaw enlarges the distance," (interval.) "For the same reason the mouth of the antique will be the smallest." Camper, p. 43, 44, of the Work above quoted.

plate iii. fig. 7.) In front, as in profile, the depth and breadth of the head retain the same ratio to each other as in adults: but the length or height is less in children by one-twelfth. This diminution being made at the chin, A B is divided as before (Art. 224) into five equal parts, two of which form the radius of the upper circle, and the three lowest, or D B, the diameter of the lower circle. "The head," observes the author on this figure, "is only four eyes in breadth, which is the true proportion, and not five."[*]

(226.) The indispensable application of Perspective, or "the Art of foreshortening," to the outline of every object, has been insisted upon. It is, therefore, not surprising that the above rules of Camper, however correct and carefully deduced from examination of the bones of the skull, should be only partially useful; being exemplified by him on forms of heads viewed only under two aspects, namely, in front and in profile. Whereas the draughtsman, for drawing solid figures, must have "length, breadth, and thickness." (Art. 156.) The variety of other aspects, besides those given by Camper, is infinite in which the head must require to be delineated. We shall endeavour to suggest how his method may be made more extensively available to the student. For this purpose we desire the learner to regard the human cranium no longer in the light merely of an oval or plane figure, but as a spheroid or solid composed from two spheres: containing at its larger end the cerebellum; at its smaller the cerebrum.

This spheroid will be divided longitudinally and transversely by three planes.

Three planes, at right angles to each other, divide the cranium; *viz.* the maxillary, the mesial, and the coronal plane.

1. The *maxillary*, or occipital plane, containing the occipital and auditorial lines before described. (Art. 223.) Thus, the maxillary plane lvr (plate ii. fig. 8) contains the occipital line sp; and the auditorial line jq. And in fig. 9 the maxillary plane $elkf$ contains the auditorial line ki.

2. The *mesial* plane,[†] at right angles to the former, and containing, besides the occipital line, a line xz, (plate ii. fig. 7,) or ag, (fig. 9,) which forms the *axis* of the skull. Consequently in

Plate ii. fig. 7,	the mesial plane is	$zxyh$.
fig. 8,		$unot$.
fig. 9,		dcb.

3. The *coronal* plane, which contains the line of the head's axis, and also the auditorial line. It is perpendicular to the two former planes. It extends right and left from the *corona*, or crown of the head, near x; (fig. 7;) and is parallel to the perspective plane, whenever a front or full view of the face is taken. From an apprehension of crowding and confusing our diagram the coronal plane is not exemplified in the plate.[‡]

Application of Camper's method universally.

(227.) Having fixed upon some point, as s, (plate x. fig. 1, No. 9.) for a centre of motion to the head, a little above the upper vertebra of the neck, draw through s towards the corona a line Q L or $Q\sigma$ for the axis of the head, and to this draw also through s the repoesentation Ese of a perpendicular in the direction of the auditorial line. Or, if Ese be first determined, draw through s the representation Qs of a perpendicular to Ese. Let sQ represent the length of a nose, (or one-fourth of Q L, the length of the head,) at the distance of the point s, (Art. 39,) and let sL represent an interval of three noses, or three times the original of sQ. Bisect sL in S, making sS represent one nose and a half. With the point S for a centre, and for a radius the interval of a nose and a half, (at the distance of S,) which interval in this example equals Ss; describe an arc for the hinder part of the head, to include the cerebellum. Next find the vanishing point (Art. 195) of all perpendiculars to the plane containing Q L and eE, (*viz.* the coronal plane,) and draw through S a line K S towards that vanishing point.

We have now obtained the direction of three lines that belong to three planes perpendicular to each other, (Art. 154, 155,) for the purpose of expressing the length, breadth, and depth of the head; *viz.* L Q, the intersection of the mesial with the coronal plane to express the length; Ee, the intersection of the maxillary with the coronal plane to express the breadth; and K S representing a parallel to FsW, the intersection of the mesial with the maxillary plane. The line K S is producible at either extremity K or S for expressing the depth or distance from the forepart to the back of the head.

The next operation is to cut off from these three lines or their parallels, the required proportions. For this purpose, choose in σQ some point, as σ, sufficiently distant from the figure not to confuse its outline. Join the vanishing points of the lines K S and Ee, or of F W and Ee. Thus will be obtained the vanishing line of the maxillary plane. (Art. 31.) It is, in this example, the horizontal line. Through σ draw a base to this plane. Find now the proportionate length of a nose, or fourth of L Q, at the distance of the point σ. (Art. 39.) In the present example that fourth is the same size at σ as at S or s, since $Q\sigma$ is parallel to the picture. Through σ draw representations, $k\sigma u$ and $\epsilon\sigma\rho$, of parallels to the occipital and auditorial lines, *viz.* to F W or K S, and to Ee. Then, on the base κw, mark off the proportions following:—

	Number of Noses.		
$\kappa\sigma$	$1\frac{3}{4}$	represented by	$k\sigma$ and K S.
$\sigma\epsilon$	$1\frac{1}{4}$		s E.
$\sigma\mu$	$1\frac{1}{2}$		σm and S M.
$\sigma\omega$	$1\frac{1}{2}$		$\sigma\rho$, $m\xi$, mz, and σx.
$\sigma\tau$	$\frac{3}{4}$ or $\frac{1}{4}$ of L s		σt, S T, and L l.

Observe, that in the transfer of these proportions from $\epsilon\sigma\rho$ and $k\sigma u$ at σ, to the parallel representations at S and s, the transferring lines represent parallels to σQ: so that in case σQ be not parallel, as in this example it is, to the picture, they must be drawn to the vanishing point of σQ.

Having thus obtained the point T for a centre of the cerebrum, find Tl, the representation of SL at the distance of T. (Art. 39.) From Tl cut off, according to Camper's rule before stated, (Art. 224,) one-ninth part, and, with the remainder as a radius, describe an

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[*] Accordingly, to find the outer corners of the eyes take off an eighth from each extremity of the line which determines their direction. The intermediate portion may then be divided into three eyes.

[†] This term is familiar to Anatomists. Its Greek derivation (μεσος, middle) implies its use in dividing the right half from the left throughout the body. Dr. Barclay, in his celebrated Work on muscular motion, has introduced this and many other significant terms contributing essentially to clearness.

[‡] The line of the horizon varies in the three examples given. In fig. 7 the horizontal line is wh. In fig. 8 it is above the head; in fig. 9 below it: the point C, in the latter figure, being the centre of the picture. The centre of the head's motion is m.

arc for the forepart of the head to enclose the cerebrum.*

(228.) To draw the eyes and features. Let $m\,\sigma$ be the representation of $\mu\,\sigma$, and $k\,\sigma$ of $\kappa\,\sigma$. Through k and m draw $k\,b$ and m B, representations of parallels to σ Q: the former, $k\,b$, in the plane of the forehead, the latter, m B, in the plane of the inner corners of the eyes. Let A B be divided similarly to L Q into four divisions or noses; and through o its centre let X x represent a parallel to ϵ E, the auditorial line. To find the proper length and divisions of X x, let Z z represent a parallel to it drawn through m. Through ρ draw the representation of a parallel to $\sigma\,k$, cutting Z z in z. A line from the dividing point (Art. 85, 102, 133) of z Z will cut the base $m\,\xi$ in ξ. Make $m\,\Xi$ equal to $\mu\,\xi$, and find m Z its representation. Finally, transfer $m\,z$ and m Z to the parallel at o, and you obtain X x, the representation of $\Xi\,\xi$. The usual proportional divisions of $\Xi\,\xi$ may be then applied to Z z and X x.

The draughtsman will be careful to observe, that of the two corners of the eye, the inner one towards the nose is the more prominent. In other words, a straight line from the outer to the inner corner will not represent a parallel to X x, but will make some angle here represented by $c\,o\,x$. Let that angle be first ascertained, in the vanishing line of the maxillary plane, on each side of the vanishing point of x X. In the present example it is an angle of 5 degrees. Therefore $c\,o$, for the line of the left eye, will vanish at the point graduated 50°, or 5° beyond the vanishing point of x X; while the similar line for the right eye will vanish at the point graduated 40°, or 5° short of the vanishing point of x X. It seems unnecessary to add, that the representation of the parallel to $c\,o$, passing through the eye itself, must vanish in the same point (Art. 76) with $c\,o$.

The facial line comes next to be determined. It belongs to the mesial plane, whose vanishing line in this example crosses the horizontal line perpendicularly at the vanishing point of A L, K S, F W, or G Q, with any of which lines the facial line makes, what Professor Camper styles, the facial angle. In the present example it will be seen, that all the varieties of that angle in the human subject are included between K P G and K F G: K P G for the antique, or Grecian form; K F G for the negro cast. For the antique, a facial line from K, drawn through F W at its point of intersection with A B, will at all times give very nearly the required angle 100°. The representation K G Q being of an angle of 100°, that of G K S will be 95°, F W will give the place of the nose, between which and B let the usual proportion of one-third be taken for the place of the mouth. In drawing the ear, observe the projection of a prominent point in its upper curve at R in the same plane with the auditorial line at E. In this example $\sigma\,\rho$ represents this projection; in like manner, as $\epsilon\,e$ represents the projecting interval of the lobe from the axis σ Q. Lines ρ R and ϵ E, representing parallels to the axis, will transfer these required projections, originating from $\sigma\,\epsilon$ and $\sigma\,w$, on the base $\kappa\,w$.

(229.) For the heads of children and aged persons, the rules of Camper will be found equally available. For drawing the heads of children, let a twelfth part of L Q or A B be taken off at their lower extremity for the place of the chin, and the remainder divided into five noses. For aged persons, the curtailment of the chin, and its protrusion beyond the facial line, will mark sufficiently, as has been seen, their peculiarities of facial outline. (Art. 224.)

(230.) A similar process will lead to accuracy in delineating the head of any animal.* An example is given (plate viii. fig. 5) in a skull of the common domestic cat.† It is recommended to the student to place the cranium of whatever animal he proposes to study, upon a square board, $a\,b\,c\,d$, in the manner here represented, having the maxillary plane parallel to the plane of the board, and the mesial plane cutting the board in the diagonal $b\,d$. The vanishing point being then found of the auditorial line will be the centre of the vanishing line of the coronal plane. (Art. 145.) Fig. 6 exhibits the same head completed.

This practice adopted for the outline of the heads of various animals will promote general facility and fidelity. The artist, according to his acquaintance with the bones, will proportionably and, almost insensibly, obtain precision in marking the muscular integuments. Nor let him be startled by the multiplicity of forms throughout the animal crania.‡ His difficulties are not greater than are surmounted by an Architect who draws a perspective view of any building. If, previously to an architectural drawing in perspective, the draughtsman be prepared with a ground plan, together with an elevation of the two sides exposed to the spectator, these materials are sufficient for representing "length, breadth, and thickness." In like manner, when a part of the animal edifice is to be delineated, let figures 2 and 3

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* Care must be taken, in fixing the proper lengths of the *radii* at S and T, that they be both drawn parallel to the vanishing line of the mesial plane, in order that they may always be both also parallel to the picture. (Art. 80, 123. See also Prob II. and Prob. VII.)

* Mr. Chalon, in a very clever Drawing book, divides the head of a horse into four equal parts. (See plate viii. fig. 11.) He has for this the authority of Stubbs, who in his celebrated Work estimates his proportions from the length of the head. "This length," he says, "is taken from the top of the head to the ends of the cutting teeth, and is divided into four equal parts, each of which is again divided into twelve minutes." *Preface to the Anatomy of the Horse*, by George Stubbs, Painter. Lond. fol. 1766.

† The artist cannot be too familiar with the external bones of the cranium and its neighbourhood. We advise him to examine them with all the zeal of a Phrenologist. We choose for our example the skull of the domestic animal above mentioned, to show that materials for useful study are within the reach of every one. The prevailing taste for Zoological inquiry bids fair to induce a corresponding progress in animal-painting. But without recurring to the growth of foreign climes, examples at home are sufficiently numerous and deserving of artistic examination. In the class mammalia, for instance, not to mention the ordo *bi-manus*, or Man, we have the third, fourth, fifth, sixth, and seventh orders, (as laid down by Blumenbach,) inviting our notice, natural co-tenants of the same native soil with ourselves. In the third order we have the bat. Among animals in the fourth, or *digitata*, we have the mouse and rat, the hare and rabbit, the mole, the dog and fox, and the cat. In the fifth, or *solidungula*, the equus, horse or ass; in the sixth, *bisulca*, the sheep and goat, the ox, the deer; and in the seventh, or *multungula*, (the pachydermata of Cuvier,) we have the pig. (See Lawrence's *Manual of Comparative Anatomy, from the German of Blumenbach*, 8vo. 1827.)

‡ The junction of the head with the neck in quadrupeds is not as in man equidistant from the anterior and posterior extremities of the skull. According to Daubenton, the plane of the foramen magnum in man is nearly parallel to that of the horizon, making with it only an angle of three degrees. But quadrupeds have the occipital foramen and condyles situated further back in proportion as the face is elongated. That opening too, instead of being nearly parallel to the horizon, forms a considerable angle with it, which, measured according to Daubenton, is of 90° in the horse. The weight of the head therefore in these animals is not sustained by the spine, but by a ligament of immense strength, which, in the human subject, is either deficient, or so weak as to have its existence disputed. This is the *ligamentum nuchæ*.

(plate viii) be regarded as two elevations, (fig. 2 for the front and fig. 3 for the profile,) while fig. 4 expresses the ground plan of the head: the several proportions so laid down may be transferred faithfully to the perspective plane and represented as in fig. 5.*

Motions of bones in the region of the head.

(231.) On the *motions of which* the *bones* in the region of the head *are capable*, we again refer our readers to the anatomical portion of this work. The hinge-like motion of the lower jaw upon its condyles admits (in the human subject) of opening the mouth till the distance between the edges of the upper and lower front teeth nearly equals the breadth, when the lips are closed, of the mouth itself. The lateral motion, where lateral motion exists,† is greater or less at the front of the mouth in proportion to the projection of the maxillæ; and according to the order or genus by which any particular animal is distinguished. Birds move both the upper and lower jaws, and their crania require therefore peculiar attention. Respecting the neck, generally, it may be considered in the light of a massive chain of bones, (to the number most commonly of seven in mammalia, and of many more in birds,) each bone linked to its neighbour by intervening ligaments. In the human neck this chain is short compared with that of many mammalia, as the horse, camel, &c. Its average length in man is nearly three noses, or three-fourths of the head; and in front, from the chin to the pit between the clavicles, about two noses. To measure on all sides, in its utmost extent, the motion of this chain of the human neck, we may proceed thus. Either the upper end of it is fixed as when a weight is to be balanced and supported on the head, in which case the lower end, as in plate vii. fig. 3 and 4, is capable of describing the base of a cone equal to perhaps, at the utmost, two noses in diameter. Or else, as happens in ordinary cases, let the lower extremity of this bony chain be fixed. In such cases, the head at the upper end may be said to describe an orbit‡ which would be the base of a cone equal in diameter to the base of the former one. But observe in both cases that as the diameter of the base increases the altitude of either cone diminishes.

Action of muscles in the region of the head.

(232.) The visible *muscles* in the region of the head which regulate its motion are, 1. *temporalis*, passing downward behind the zygoma to the coronoid process of the lower jaw, and pulling the lower jaw upwards, as in chewing food.§ 2. The *masseter*, passing over the insertion of the temporalis, and extending from the cheek bone and zygomatic process of the temporal bone to the angle of the lower jaw, which it also pulls upwards. 3. The *sterno-cleido-mastoid* muscles, which pass upwards from the sternum and sternal end of each clavicle to the mastoid processes behind the ears. By the contraction of one or other of these muscles, the head is turned to one side; by the contraction of both of them, the forehead bends forward, as in bowing.* 4. Observe two muscular columns one on each side of the bones of the neck beneath the *trapezius*, which they contribute to fill out, elevating the head backwards, keeping it erect when raised, and assisting its rotatory motions.†

Of O

The other muscles of the head relate to motions of the eyes, eyebrows, nose, mouth, and ears, and of the bone of the tongue, or os hyoides, so called from its resemblance to the Greek upsilon. They will be spoken of when we come to treat of Expression. But besides knowledge of the superficial muscles, the artist will do well to acquaint himself generally, at least, with the course of the blood-vessels of the head and neck; that of the temporal artery, with its transverse and frontal branches; of the facial vein, the jugular, &c.‡ Colour, as well as form, will frequently depend upon his intimacy with these parts of the animal system.

Region of the thorax. Its bones.

(233.) THE REGION OF THE THORAX comes next in order, bounded, in the human subject, posteriorly by the seven uppermost dorsal vertebræ, in front by the sternum, and on the right and left by the scapulæ and the seven true ribs.§ The remaining five ribs partly enclose the abdomen, and may therefore be considered in that separate region. The bones which protrude most, and of which the markings are to be chiefly noticed, are 1. the *sternum*, or breast bone, making, on account of its vibratory motion, an angle with the plane of the topmost ribs that varies (in the human sternum) from 50 to 38 or 40 degrees, according to the extent of exertion in breathing. 2. The *claviculæ*, clavicles, or collar bones, are to be noticed particularly at their extremities; the inner extremities joined to the head of the sternum, the outer to the acromion of the scapula. The clavicles are wanting in most orders of mammalia. 3. The *scapula*, or shoulder-blade, a triangle of different shapes and dimensions in different animals. Observe the ridge called its spine, crossing it like a perpendicular drawn from its angle at the shoulder to its opposite side, which is therefore named its base. Remark also, nearly in the plane of this ridge and of this perpendicular at the angle last mentioned next the shoulder, two processes,‖ having the

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* In fig. 7 and 8 is given a head of the pig; and in fig. 9 and 10 a head of the horse.

† The lower jaw of the carnivora can only move upwards and downwards, and is completely incapable of that horizontal motion which constitutes genuine mastication. Hence these animals *cut and tear* their food in a coarse manner and swallow it in large portions, which are afterwards reduced by the solvent properties of the gastric juice. Such mammalia, on the contrary, as live on vegetables, have, in addition to this motion, a power of moving the lower jaw backwards and forwards, and to either side, so as to produce a *grinding* effect. In all these, therefore, the form of the condyle and of its articular cavity allows of free motion in almost every direction. The teeth may be compared, in the former case, to scissars; in the latter to the stones of a mill. Lawrence's edition of *Blumenbach's Manual*, 8vo. Lond. 1827, p. 28.

‡ The well-known trick of Harlequin, in Pantomimes, of rolling his head, exemplifies the motion here alluded to. On simple and compound motions of the neck, see L. da Vinci, *Trattato della Pittura*, ch. 484.

§ The semicircular cavity on the right temple of the skulls in plate ii. fig. 7 and 8, is filled up by the temporalis with its fascia.

* In cattle, as in the horse, (see Plate of the Horse muscles,) the levator humeri and the sterno maxillaris perform this office.

† The complexus major, the splenius, and the ligamentum nuchæ, in cattle, form this column. See the Plate of the Horse muscles.

‡ In the horse, the external carotid, or submaxillary artery coming out under the angle of the lower jaw, to climb up over the face, also the jugular where it divides under and behind the ear, are conspicuous.

§ "In almost all the mammalia there are more ribs than in Man. Several quadrumana have fourteen pairs, the horse eighteen, the elephant twenty, &c. Birds have fewer ribs than mammalia, the number, I believe, never exceeds ten pairs. The false ribs, that is, those which do not reach to the sternum, are *directed forward*; the true ones are joined to the sternum by means of small intermediate bones." Blumenbach, *Manual*, p. 46, and p. 63. By the expression "directed forward" is meant that they are nearest to the neck.

‖ The margin (of the scapula) which is turned towards the spine, is the shortest in most of the proper quadrupeds, particularly the long-legged ones with narrow chest, in which the scapulæ lie on the sides of the chest. The coracoid process and acromion, the two chief projections of this bone, are strongest in such animals as have a long clavicle, p. 49, 50.

head of the humerus in the glenoid cavity between them: one process, the *coracoid*, on the side of the cavity nearest to the sternum ;[*] the other process, the *acromion*, above and outside of it towards the right or left. 4. The arm, foreleg, or wing, composed of the *humerus*, *radius*, and *ulna*. The two latter throughout the animal kingdom are often found consolidated. In the round head of the humerus observe the bicipital groove.[†] 5. The hand and wrist composed of the *carpus*, *metacarpus*, and *phalanges*. The articulations of the carpus with the radius (always on the side of the thumb) and with the ulna (always on the side of the little finger) require minute attention.[‡]

(234.) For determining the relative position of bones in the region of the thorax ; imagine, as before, (Art. 226,) a geometrical solid figure, which will enclose the principal parts. Let this solid be traversed, as was the skull, (Art. 226,) by certain imaginary lines and planes. Thus let $s\,v$ (plate iii. fig. 8) show the angle made by the sternum with the plane of the upper ribs; *viz.* the angle $v\,s\,t$; and let $s\,v$ be called the line of the sternum, or *sternal line*. Again, the line $t\,r$ or $s\,r$ joining the top of the sternum to the centre of the first dorsal vertebra, we may term the *sterno-dorsal line*. The plane $u\,r\,t\,v$ containing those two lines, (the sternal and sterno-dorsal,) and passing through the body to the back,[*] dividing the right from the left half, is the *mesial plane*. Also the plane $g\,h\,e\,f$, (fig. 9) at right angles with the mesial, may be termed the *supercostal plane*, giving the direction of the uppermost pair of costæ, or ribs ; which plane, in the erect human figure, is nearly parallel to the horizon.

Of Outline.

Sternal and sterno-dorsal lines found in the mesial plane.

Supercostal plane.

(235.) The thorax has been generally compared to a truncated cone. But perhaps its outline would be gathered more satisfactorily by enclosing it within a kind of pyramidal figure (of which a bird's eye view is given in plate iii. fig. 9) having four sides, two of them flat, as $a\,b\,h\,g$, and $d\,c\,e\,f$; the other two curved, as $h\,b\,k\,c\,e$, and $a\,l\,d\,f\,g$. The two latter sides indicate the right and the left of the trunk ; as the two former indicate the back, and pectus or breast. Let, then, $a\,b\,c\,d$ contain a transverse section of the trunk cutting the mesial plane in the line of intersection $m\,p$, which is intended to represent the distance from the bottom p of the sternum to the outside, m, of the back, at the spinous process of the seventh dorsal. The sixth pair of ribs will be $b\,k\,c$ and $a\,l\,d$; and $m\,n$ the distance from n, between the junction of their cartilages at the sternum, to m, the spinous process of the sixth dorsal.

(236.) In order to make as near an approach as may be required, to the curves of these ribs, bisect $m\,n$. Draw, through the point of bisection, the perpendicular $k\,l$, on each side of which let the interval $i\,o$ equal the broadest part $e\,f$, of the sternum, (about the length of a nose,) and make $d\,c$ and $a\,b$ equal to twice $i\,o$, that is to twice the broadest breadth of the sternum. Next, with i for a centre, and $i\,b$ (which will be equal to $a\,b$) for radius, describe the arc $b\,k$ for part of the curve of the sixth left rib. The arc $a\,l$, similarly described about the centre o, will partly give the curve of the sixth right rib; and the lines $k\,c$ and $l\,d$ will complete them anteriorly. Behind, from b and a, the outline may be readily curved inwards to the junction of these ribs at S with the sixth vertebra. The outline also of the upper or first pair of ribs, $h\,e$, and $g\,f$, will be made nearly correct by taking the point i for a centre to form the arc $g\,f$; and the point o for a centre to form the arc $h\,e$.

The intermediate four pair of ribs may be drawn similarly to the sixth. But observe, that the lines $b\,h$, and $a\,g$, show the course of the two convex ridges, always remarkable in the torso,[†] though sometimes con-

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[*] On reexamining plate iii. fig. 8, where $v\,s\,t$ or $r\,s\,q$ represents the angle made by the human sternum with the plane of the topmost ribs, we find that $v\,s\,t$, or 50 degrees, is the highest elevation of the ensiform extremity at v. Consequently, when v declines, the angle $v\,s\,t$ enlarges. We have above inadvertently stated the variation of $v\,s\,t$ to be from 50 to 38 or 40 degrees. We should have said that the angle varies from 50 to 60 or 62 degrees.

[†] The metacarpus is elongated in those animals whose toe only touches the ground in standing or walking: and the humerus becomes shorter in proportion as the metacarpus is elongated, so that in animals which have what is called a cannon bone (that is one metacarpal, as in the horse and the ruminantia) the os humeri hardly extends beyond the trunk. Hence the mistakes, in common language, by calling the carpus of the horse his foreknee, &c. p. 51, 52.

[‡] The animals with divided claws have some peculiarities in the metacarpus. In the pig those parts consist of four cylindrical bones. In the *pecora*, before birth, there are two lying close together; but they are afterwards formed into one by the absorption of the septum. The horse has a single bone (*gamba*, Vegetius, in French *le canon*, in English the *cannon bone* or *shank bone*,) with a pair of much shorter and immovable ones attached to its posterior and lateral parts, and firmly united to it, (*les poinçons* or *os épineux*, *styloid* or *splint* bones.) The main bone only is articulated to the *pastern*, which may be compared to the first phalanx of the human finger ; as the *coffin bone* resembles, in some degree, the third phalanx, which supports the nail. This last phalanx is very various in its form, according to corresponding variations in its horny coverings, which may consist of a flat nail or claw, or hoof, &c. The mammalia generally have as many metacarpal bones as toes, that is never fewer than three, nor more than five, with the exception of the ruminants, in which these bones are in early life consolidated into one, named, as before said, the *cannon* bone. In animals which walk on the tips of the toes, or which use them as organs of prehension, the metacarpal bones are nearly of double length. The foreleg of the horse, deer, sheep, and dog is in truth the metacarpus of those animals ; and what is vulgarly denominated the foreknee, is in fact the carpus or wrist-joint. It is, as in the human subject, convex on the side which answers to the back of the hand; concave on the side which answers to the palm. The character of the perfect foretoe or finger is to consist of three rows or phalanges, excepting the first on the radial side, which has only two. In the zoophaga, which have no power of grasping minute objects, the thumb, or first toe, is parallel to the others ; and although in the genus ursus, it is of the same length with them, it is shorter in the genus mustela, and in the weasel, the dog, and the cat families. In the latter, the power by which the claws are erected only when required, and at other times thrown back to prevent them from being blunted in walking, must not escape the artist. In the *ruminantia*, the single metacarpal bone is articulated with two digital phalanges, constituting the cloven foot. In the horse, and the other *solidungula*, the two lateral toes have their place supplied as above remarked, only by two bony styles, named the *splint* bones ; situated on the two sides of the metacarpal or cannon bone. The three phalanges then of the single toe, comprising the foot of the horse, are, 1. the *pastern* bone or first phalanx, to the back of which are joined two sesamoid bones. 2. The coronet, which is the middle or second phalanx. 3. The coffin bone, being the third or unguinal phalanx, to which is attached the shuttle bone. See plate of the horse.

[*] The line from the first to the sixth vertebra of the back varies, laterally, so little from a straight line that it is in the above examples taken for one. But the case, as will be seen in the region of the abdomen, is far different with the remainder of the vertebral chain ; which is quite as diversified in its motions as the neck, and partakes of similar powers.

[†] These convex ridges are most conspicuous in the human subject. In quadrupeds, particularly in such as have long necks, the spinous processes of the anterior dorsal vertebræ are so long and prominent for the attachment of the muscles which support the neck as to make any prominency in the ribs less apparent. Minute attention to the *torso of the horse* may be seen in the inside of a well-made saddle. And observe that as these spinous processes are long upon the back for the purpose of supporting a long neck, so also they are much shortened, or altogether deficient in the neck itself, among long-necked animals, (the horse, camel, giraffe, &c.) that they may not prove a hinderance to bending the neck backwards.

cealed by the scapula. Moreover, the lines *d f* and *c e* show the anterior or pectoral extremity of each rib at its junction with the cartilage binding it to the sternum. With regard to the seventh, and remaining lower ribs, their curves seldom or never protrude beyond *b h c*, and *a l d*. Their lengths anteriorly are represented in fig. 8, and the interval *a b*, given in fig. 9, always continues the same, whatever be the curve of the vertebral chain.

It is evident that the parallelogram, such as *a b c d*, or *g h e f*, (fig. 9,) once found in the case of any pair of ribs, the vanishing line of that parallelogram will determine the perspective or foreshortening of them[*] whether the ribs be raised, as in this example, by inspiration; or whether, in expiration, a corresponding depression[†] of them takes place and increases the sternal angle *t s v*, fig. 8.

(237.) The foreshortening of the clavicle may be always known by finding its point of junction with the top of the sternum; and then determining to what plane a straight line drawn from that point to the acromion must, in any given posture of the thorax, belong. In our representation, plate iii. fig. 11, the line of the clavicle describing the arc *a b*, or *c d*, moves in a plane parallel to the supercostal plane. (Art. 234.) In fig. 10, the line of the clavicle describing the arc *e f*, moves in a plane perpendicular to the supercostal plane. For the scapula:—The proportions of the sides of the scapular triangle being ascertained, (see ANATOMY,) and the direction of the ridge called its spine; the revolutions of that triangle on its angle at the head of the humerus are determinable by the position of the arm. (Art. 241, and plate iii. fig. 12—16.)

Line of the upper arm.

(238.) Other imaginary lines will be found useful: for example, a line from the centre of the head of the humerus, to a point in its lower extremity, between the ulna and radius. This may be termed the *line of the upper arm*.

Line of the forearm.

A line from the last-mentioned point to the articulation of the radius with the os lunare of the carpus, or in other words, with the central bone of the wrist, may be termed the *line of the forearm*. It forms a longitudinal axis upon which the wrist turns in pronation and supination. See the second note to Art. 240.

Carpal axis.

Perpendicular to this last line, at its junction with the wrist, is a line from the styloid process of the ulna through the styloid process of the radius. This is a transverse axis upon which the wrist turns in waving the hand. It may be called the *carpal axis*. The carpal axis is always the intersection of two planes; one of which contains the line of the forearm, and the other is

Meta plane.

The *metacarpal plane*, passing through the carpus, between the back and palm of the hand, to the extremities of the metacarpus, and containing the tips of the knuckles of the two middle fingers.

(239.) By these or similar lines[*] (for many other and better devices will constantly present themselves to the practised artist) the foreshortenings of the limbs of the thorax may be obtained. For example, the line of the upper arm, and the line of the lower arm may always be considered in the same plane; of which plane, if the vanishing line be determined, the proportions, or foreshortenings, are easily calculated from knowing the dimensions (previously agreed upon) of the clavicle, or any standard interval, as the length of a head or a nose at the distance of the point of the shoulder. That the application also of some such system of imaginary lines must be found serviceable in delineating the thorax and brachia of quadrupeds, and of animals generally, may be inferred from plate vi. fig. 5 and 6, illustrative of locomotion. But such a system must not be over-rated. It must be applied only to the skeleton, only to the bones; only to the rafters, joists, and framework, so to speak, that support the exterior animal structure. Any other adaptation of such a system would induce a stiff, artificial, and lifeless manner, utterly inexpressive of character and of sentiment.[†]

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[*] It must, however, be borne in mind, that, in cases of contortion caused by pain or otherwise, as well as of some ordinary inclinations of the spine, the ribs, particularly those towards the abdominal region, will approach and even overlap each other on whichever side the inclination of the spine is made. Thus in walking, or standing on one leg, that side is always shortest towards which the body leans, in order that its centre of gravity or weight may be transferred to some point directly over the supporting limb; while the other side (namely, that of the leg which is being bent and lifted forward to make another step) is proportionably lengthened. Both sides are curved, but the outside curve will, of course, be the longer of the two. See for further examples in carrying weights, &c. Da Vinci, *Trattato della Pittura*, cap. 195—214.

[†] The direction of the ribs anteriorly and posteriorly is not in planes parallel to each other, but inclined to the spine at different angles; the topmost pair nearly at a right angle; the remaining lower ones at various angles of inclination increasing in acuteness as they descend to the last pair called floating ribs at the back of the abdomen. In proportion to the acuteness of their angle of inclination to the spine is their mobility and capacity of being depressed, elevated, or made to overlap each other.

[*] Among the most difficult outlines of the upper extremities will be found that of the human thumb, owing to that extensive range of motions which so justly obtain for it from Albinus the title of *manus parva majori adjutrix*, as the human hand has from Aristotle that of *the organ of all organs*. The thumb has the power of describing at the same time round two different apices a conical motion, 1. round its point of junction with the carpus; 2. round the point where its metacarpal bone joins the carpus.

[†] A work, in folio, of Juan d'Arphe y Villafañe, republished at Madrid in 1773 (a sixth edition) by Pedro Enguera, has unfolded to us much curious and some useful matter on the proportions and *foreshortenings* (*los escorzos*) of the human figure. The author, after referring briefly to the principles of drawing given in the writings of Pomponius Gauricus and Albert Durer, and of the improvements afterwards effected by Pollayuolo, Bandinelli, Raffaelle, Andrea Mantegna, Michel Angelo, and others through their introduction of the antique model, proceeds to mention the divisions which existed in the different Schools of Art, particularly in Spain, (some adhering to the old, others adopting the then new system,) until the abilities and influence of Gaspar Becerra (see his name in our short notice of the Spanish School) introduced generally among his countrymen the good taste he had acquired and formed in Italy for the Greek and Roman beautiful. At page 173 of this singular book, and towards the conclusion of some instructions, written in rhyme, for delineating the human figure, is the following in prose, of which we will here attempt a translation. It professes to be adopted from book iv. of the *Symmetria* of Durer.

"In order to make the foreshortenings alluded to, in drawing large figures, and where the eye of the spectator cannot take in the entire parts, procure a rule about the length of the intended figure, mark it off into ten equal divisions, and again divide each of these ten into three, so that the whole length may, with the addition of one, serve to measure thirty-one subdivisions. The proper length may first be laid down of each portion or member of the figure, and afterwards the breadth, as follows. Let the length of the head be four (including three for the face) out of the thirty-one parts; that of the neck one part, of the trunk from the line of the shoulders to that of the symphisis pubis eleven; of the femur seven. For the length of the leg seven more, to which add the one remaining subdivision for the distance of the highest part of the foot (between the ankles) from the ground. You will have now completed the height of the figure. Next, for the arm from the axilla or armpit (*sobaco*) to the hand, nine parts; for the length of the hand three; from the armpit to the acromion or point of the shoulder two parts: so far the length.

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(240.) Among the *motions of which the bones* in the region of the thorax *are capable*, that of the sternum has been noticed. (Art. 233, 234.) During *inspiration*, or the act of taking breath, the thorax is dilated; the ribs raised and drawn outwards to the right and left, pressing the lower portion of the sternum forward, while its upper extremity between the clavicles remains fixed; and thus decreasing the angle *r s q* or *v s t* (plate iii. fig. 8) made by the line of the sternum with *r t*, the sterno-dorsal line. In *expiration* the contrary motions are produced. The ribs fall. The sternum sinks. The sternal angle *v s t* increases.

The motions of the human arm* and hand† are analogous to those of the wing in birds,‡ and of the foreleg in quadrupeds; but infinitely exceed them as to number and variety. There are five principal kinds of motion in the human arm, which have been denominated, 1. *Propulsion*, (pushing or striking.) 2. *Tractation*, (dragging or pulling.) 3. *Constriction*, (embracing, *viz.* the act of closing forcibly, sometimes one or both arms, sometimes one or both hands.) 4. *Diduction*, (forcible separation of those members as in swimming.) 5. *Circumduction*, an act confined to the head of the humerus, so placed as to admit of describing, backwards, forwards, or sideways, a conical figure, of which a point within the glenoid cavity is the apex, while another point between the condyles describes the base.* Let the reader endeavour to draw with chalk a circle on a wall either in front of, or to one side of him. This will exemplify circumduction. The motion of the wrist (known to fencers in changing its position from carte to tierce, or *vice versâ;* and by anatomists called pronation and supination†) is, in part, rotatory.‡ The phalanges of the thumb and fingers have likewise at their junction with the metacarpus a degree of rotatory action, though otherwise they have only a similar motion to that of the elbow during flexion and extension of the arm, *viz.* a hinge-like motion, as in opening and shutting the hand.

(241.) But we have yet to notice the motions of two other bones which contribute essentially to vary the position and outline of the humerus. These are the clavicle and the scapula. The clavicle may be said to describe a small cone, of which the apex is at its junction with the top of the sternum. Its outward extremity, joined to the acromion, either rises, as in shrugging; or retires, as in throwing back the shoulder; or comes forward, as in the case of persons vulgarly termed round shouldered. The extent of the arc described by the

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"Next as to breadth. Let the head in front be three parts broad, and the same behind. In profile (*por el lado*) let its breadth measure four; for the breadth of the neck take two parts, of the trunk at the shoulders, eight, and of the same in profile, five; of the trunk at the armpits, six, and of the same in profile, five; of the waist five in front, and four in profile; of the haunches six in front, and five in profile; of the femur, at its upper and thickest end, three in front, and three in profile; of the knee two parts in front, and the same in profile; of the calf two and a half in front, and the same in profile; breadth at the ankles one part in front, one and a half in profile; breadth of the foot one part at the heel, and four for the foot in profile, *viz.* for the whole length of the sole. After this measurement proceed to give roundness to the figures by suitable muscular boundaries. Breadth of the upper arm, at its middle, in front one part and a half, in profile two parts; of the forearm at its thickest end, two parts in front, of the same in profile one and a half; of the wrist, one part in front, and three-fourths of one part in profile; of the hand, two in front, and one half in profile." (See plate vi. fig. 7.)

The above quotation is the more available for our method of fixing certain imaginary lines, since each of the thirty-one subdivisions measures a nose, or fourth part of the length of a head. (Art. 222. 227.) The front of the neck, it will be observed, is here made one nose in length, (which is also the proportion in Camper,) whereas we have given it in Art. 231, a length of nearly two noses. Perhaps our measurement is only proper for certain subjects; but the student will find in nature as great diversities. Again, with respect to the head, we make the breadth of the cerebellum to that of the cerebrum as nine to eight, (Art. 224. 227,) whereas according to the above scale their breadths are equal. This seldom happens, as the student may at any time prove to himself, with a pair of callipers, upon the heads of his acquaintance. Of the changes made by age in the proportion of the figures, see Da Vinci, *Trattato della Pittura*, cap. 57. 167—169. 173.

[*] Observe that the upper arm and forearm when stretched out never form one and the same straight line. This arises from the structure of the elbow, at which there is always more or less an angle. Neither is the hinge-joint of the elbow so placed as to be perfectly at right angles with the plane of the upper arm on which it hinges; but the ulna moves obliquely upon its hinge, so as to permit the forearm to be drawn forwards over the breast while the elbow remains close to the side.

[†] Let a straight line from the centre of the outer condyle of the humerus be drawn to the centre of the wrist, for the axis of the forearm and hand in pronation and supination. Let another straight line, at right angles with this, be drawn through the lower extremities of the cubit joining the radius and the ulna. On the latter line, the axis of the wrist, the carpus turns, as on a hinge, either alternately from side to side with a rudder-like motion; or alternately up and down, like a wing, according to the position of the forearm. (Art. 238.)

[‡] The bones of the wing may be compared, on the whole, to those of the upper extremity in Man, or the quadrumana, and consist generally of an os humeri; two bones of the forearm; one of the carpus; one bone of the thumb; and two fingers, of which that which lies towards the thumb consists of two phalanges, the other only of one. Blumenbach's *Manual* by Lawrence, p. 64.

[*] *Centrum ceu fulcimentum ossis humeri vel femoris existit præcisè in medio illius tuberculi qui in sinuosâ cavitate scapulæ, vel coxæ immobilis infigitur et colligatur: et hisce duobus articulis extremitas semidiametri mobilis, ejusque centrum est prominens et exporrectum: e contra centrum semidiametri circumductionis cubiti existit extra cubitum in medio, nimirum tuberculi humeri quiescentis, cui ille alligatur et* circumvolvitur*; et idem dicendum est de reliquis similibus articulationibus.*

Notandum pariter est, quod motus articulorum aliquando sphærici sunt, aliquando in uno plano alicujus circuli, multoties in superficie conicâ *existant. Regula generalis esto, quotiescunque motus unius ossis undequàque fieri potest circa unicum punctum fixum, tunc quidem motus sphæricus erit; scilicet ad dextram, ad sinistram, sursum, deorsum, antè, et retrò; quoties vero motus fieri debet circa duos polos; vel circa axem necessario motus et circumductio, aut in superficie planâ circulari, aut in superficie conicâ efficietur.* Borelli *de Motu Animalium*. 2 vols. 4to. Romæ, 1670; Pars 1ma. c. 4. prop. ix.

According to this quotation, it should seem, that, since in the case of *circumduction*, as above illustrated, the revolving point between the condyles has power of describing the base of a cone in various directions, (*ad dextram, sinistram, sursum,* &c.) its motion might, perhaps, more strictly be termed spherical. But either term, "conical" or "spherical," will express our meaning. As we regarded a circle (Art. 181) in the light of a regular polygon with its sides composed of indefinitely small chords: so may the surface of the sphere be considered as composed of an infinite number of small bases of cones having equal *axes* and dimensions and a common apex in the centre of the sphere.

[†] In *supination*, the bones of the radius and ulna are situated in lines parallel to each other. In *pronation* the lower end of the radius where it joins the hand is carried over and round the ulna, so as to cross it and form a very acute X, of which one line (the line of the ulna) will extend from the wrist (on the side of the little finger) up to the olecranon, or point of the elbow. The other line (or line of the radius) will be extended *over* it, (or *under* it when the arm is thrown backwards,) and will be extended from the wrist on the side of the thumb, up to the outer condyle of the os humeri.

[‡] In the zoophaga the radius and ulna, though separate, are void of rotatory motion; and the olecranon, or projection of the ulna at the elbow, is compressed and continued further back than in Man. In the pachydermata, as the pig and elephant, the radius is before and the ulna behind, and though distinct, there is no rotation. In the ruminants the ulna is united immovably to the radius, and in the solidungula, as the horse, it is represented by an olecranon adhering to the posterior surface of that bone.

clavicle and acromion is partly shown in plate iii. fig. 10, 11. In fig. 10 the motion from *e* to *f* is in a plane perpendicular to the mesial plane. In fig. 11 the motion from *a* to *b*, and from *c* to *d*, is in a plane parallel (when the subject stands erect) to the horizon.

The scapula assists, follows, and indicates in its motion the track of the humerus and clavicula. Its position when the arm hangs by the side is with its base parallel to the eight upper vertebræ of the back. In this position it lies over all those eight ribs, except the first, which is too small to reach it.* When the arm is raised, as preparatory to striking a blow, the scapular triangle turns upon the acromion as upon a pivot. Its inferior angle is drawn upwards and outwards along the side, and its superior angle downwards and backwards from the second rib as far as the fourth. When the blow is being struck, the scapula retraces rapidly its course: and if the arm is driven far behind, and with the elbow near the back of the person striking; the triangle undergoes a yet further change, and has its inferior angle drawn upwards and backwards, till it approaches the vertebral column. An attempt is made to illustrate this in plate iii. fig. 12—15. These motions of the scapula are distinctly observable in the living subject.

Action of muscles in the region of the thorax.

(242.) Of the marked and leading *muscles* in the region of the thorax, it will not be expected that we do much more than again refer the reader to our pages on Anatomy. The pictorial student will find it useful to class the thoracic muscles according to two perfectly distinct functions performed by them; and to consider separately, 1st, such as are concerned in breathing, and 2dly, such as give motion and power to the adjoining limbs. Although breathing in general is an involuntary act, yet many cases occur when by a strong effort of the will a larger portion of air is taken into the lungs than usual.† This happens whenever any great weight is either to be resisted, pulled, or lifted; or in striking a heavy blow; throwing any missile to a distance; calling loudly; calling with a protracted sound or succession of sounds; or, lastly, in circumstances of pain or surprise, or any sudden transport of passion.‡ Notwithstanding that the muscles which are principally concerned in inspiration, or the act of *taking* breath, are concealed from view, *viz.* the *diaphragm*, the *intercostals*, the *serrati postici*, &c. (concealed in front by the *pectorales* and other muscles; concealed on the back by the *trapezius*, and *latissimus dorsi*, &c.) yet they contribute, by dilating and raising the ribs, protruding the lower end of the sternum, and lessening the sternal angle, (Art. 234, 240,) to give greater prominency to the outward and visible muscles of the thorax.*

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* In the horse, the point of the scapula close to which the humerus attaches, is between the first and second ribs; the base at its hinder part, reaches as far back as the seventh rib. The scapula, consequently, lies in a slanting position along the chest.

† For an account, in popular language, of the process of breathing, see in the *Library of Useful Knowledge*, already referred to, the Treatise on *Animal Physiology*, p. 95.

‡ The abdominal muscles contribute essentially to assist their neighbours in the higher region of the thorax during the process of inspiration. "There are few motions or attitudes of the trunk," says Dr. Barclay, "or compressions of the viscera in which these muscles" (the abdominal) "are not concerned as moderators, motors, or directors. The state of respiration is not only varied according to their different functions, but made to contribute to the steadiness and energy of their exertions. Thus in their vigorous exertions to change or preserve the attitudes of the trunk, or compress the viscera, the ribs are previously somewhat raised, or drawn *atlantad*," (toward the *atlas* vertebra, *i. e.* upwards,) "and are made to resist, as fixed points, the motion *sacrad*," (toward the *sacrum*, or downwards,) "with more than usual steadiness. This steadiness, however, does not proceed, or proceeds but little, from the intercostals. These muscles, opposed by the great pressure of the atmosphere from without, have not strength to elevate the ribs, unless assisted by a great pressure of atmosphere from within. The abdominal muscles, always favoured by the pressure from without, would, with no great exertion, depress the ribs and expel the air, while the intercostals would have no power to prevent its egress. To account, therefore, for the more than usual stability of the ribs in cases of extraordinary exertion, we must have recourse to those muscles by which the egress of the air is prevented, or by which the quantity issuing from the lungs in a given time is accurately regulated. These are the muscles of the os hyoides, of the cartilages of the larynx, of the velum pendulum, of the tongue, and of the lips. By them the passages through the larynx, isthmus faucium, mouth, and nostrils, may be widened, narrowed, or entirely shut; or one passage shut, and another opened; or the whole of them shut, and the whole of them opened, as the will directs, and as circumstances require. These muscles retaining the breath after full inspiration, or regulating the quantity that issues in a given time during expiration from the lungs, cause the air in the lungs to afford that support or stability to the ribs which enables the diaphragm and abdominal muscles to act with steadiness and energy in giving attitude and motion to the trunk. As mental emotions, too, do not unfrequently extend their influence to respiration, so the same muscles make respiration to extend in its turn its influence to the mental emotions. Hence we see that persons under surgical operations hold hard their breath, trying, as it were, to lessen their sufferings or to confirm their resolution in supporting them. A fact too obvious to have escaped the admirable Shakspeare, who makes Henry say, addressing his soldiers at the siege of Harfleur,

> 'Now set the teeth, and stretch the nostril wide,
> Hold hard the breath, and bend up every spirit
> To its full height.'

As respiration is thus made to favour the motions and attitudes of the trunk, so these motions and attitudes are made, in their turn, to favour respiration." *Muscular Motions of the Human Body*. By John Barclay, M. D. Edinburgh, 1808, p. 535.

* Those internal muscles have likewise powerful assistance from without, in a corresponding arrangement, as occasion may require, of the adjacent parts of the body. The power of the *serrati postici superiores* to move the ribs is increased by bending the neck forwards. This inflection, together with that of some of the dorsal vertebræ, gives to the trapezius, the rhomboideus, and the levatores scapulæ an extent of action on the scapula. The consequent elevation of both scapulæ renders further assistance for raising the ribs available not only from the serrati magni, but from the subclavii, the serrati antici, the pectorales, and latissimi dorsi. The three last-mentioned pairs will be visible to the student upon the living figure, and sufficiently distinguishable. Let him, for an example, observe the pulmonary cough of a consumptive person, or watch any one in the act of sneezing. The scapulæ of that person are drawn upwards and forwards; (Art. 241;) the shoulders rounded; the head and neck placed in positions most favourable to those muscles which enlarge the thorax and admit a fuller supply of air to the lungs. For another example, let a race-horse be observed at full-speed, extending his neck forwards as far as he is able, that the air passages may be straight and the quantity of air inspired as large as possible. Another reason for this action in quadrupeds, when they run, is, that their centre of gravity, or weight of the whole superincumbent body, may, by this position of the head and neck, be thrown forwards, and thus their rapidity in running be considerably increased. It will be seen, too, (see our plates of the Horse,) that the *levatores humeri* muscles (in cases where the animal has not breath for running, or even for walking or lying down, and therefore must stand) have a use in assisting the lungs, similar to their use in the case of a consumptive human subject. The artistic reader will, perhaps, be here obliged to us for extracting and combining, in the form of a note, some particulars of the muscles above alluded to belonging to the Horse.

1. The *sterno maxillaris*, of no great bulk or strength, and lying immediately under the skin, bends the head towards the chest.	1. Arising from the cartilage in front of the breast bone, (sternum,) changes, at about three-fourths of its length upward, to a flat tendon to be inserted into the lower jaw.
2. *Levator humeri* is much larger than the last mentioned, having more work to perform.	2. Arising from the occiput and four first bones of the neck and from the *ligamentum nuchæ*.

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nerus.

(243.) With respect to the muscles which give motion to the limbs of the thorax,[*] the student will naturally class them according to the parts which they move, and the direction in which the movement is made. For the *humerus*, for the *forearm*, and for the *hand*, peculiar muscles are required. We have already mentioned (Art. 241) the variations in the position of the acromion, or extremity of the clavicula, near the head of the humerus, which change from time to time the centre of rotatory motion in the human arm.[†] The conical motions of the humerus round that centre, or middle point in the glenoid cavity, (Art. 240,) will be effected *upward* and forward by the deltoides, the biceps brachii, and pectoralis,[‡] *upward* and backward by the deltoides and trapezius,[*] *upward* and outward (*i. e.* to the right or left in a plane perpendicular to the mesial plane) by the deltoides, the infraspinatus, and the teres minor. The *downward* motions (which are always assisted by the weight of the arm) are directed forward by the pectoralis;[†] backward by the trapezius, the latissimus dorsi, the longus, or long head of the triceps, the teres major,[‡] and the infraspinatus; and downward generally by the lower portion of the pectoralis, jointly with the action of one or more of the others.[§]

Its office is twofold. Suppose the animal standing, and that his head and neck are fixed points, the contraction of this muscle will draw forwards the shoulder and arm. Or, if the Horse be standing, and the shoulder and arm be fixed points, this muscle will depress the head and neck.	On its way down to the shoulder it mixes itself with some of the muscles of the shoulder, and is inserted into the humerus.
3. *Trapezius*, a quadrangular muscle, like that of the same name and similar office in the human subject, lies between the withers and upper part of the shoulder-blade. It is for supporting or raising the shoulder, and drawing it at the same time backward.	3. Arising broad and strong, from the longer bones of the withers and from the ligament of the neck, (note 3 to Art. 232,) becomes narrower below till it terminates nearly in a point to be inserted into the top of the spine, or ridge of the scapula.
4. *Serratus major*, the great saw-like or tooth-shaped muscle of immense power, fills up the greater part of the neck at its lower extremity. This muscle attaches the shoulder to the chest, and thus supports the weight of the body. When the quadruped is standing this muscle occasionally discharges another important function. Since by the weight of the body, the shoulders and legs are then rendered fixed and immovable, the serratus major, no longer employed to raise the limbs, exerts its power in *enlarging the cavity of the chest*, and thus materially assists in the act of breathing. It is on this account that a horse labouring under inflammation of the lungs will obstinately stand night and day that he may obtain the assistance of this muscle in respiration. The power also of the *serratus major* in obviating concussion, is of immense importance to the Horse as well as to his rider. Its action, with that of the other muscles attached to the inner surface of the scapula, has been well compared to that of the springs of a carriage, but possessing infinitely greater steadiness, mobility, and strength. These muscles yield, as far as necessary, to the force or superincumbent weight. By *gradually* yielding they subdue the violence of the shock, and through their elastic properties, immediately regain, when the shock is over, their original position.	4. Arising from the five lowest bones of the neck and the two first ribs. Its lower portion springs from all the true ribs. Its fibres all tend downwards, and are inserted into the *inner* surface of the shoulder-blade or scapula, *i.e.* between the scapula and the ribs.

[*] The true quadrupeds have the front of the trunk supported by the anterior extremities, which are consequently much larger and stronger than in Man; as the hind feet of the same animals yield in these respects to those of the human subject. The chest is, in a manner, suspended between the scapulæ; and the serrati magni, which support it in this position, are, consequently, of great bulk and strength. When viewed together, these muscles resemble a kind of girth surrounding the chest. Blumenbach, *Manual*, p. 309.

[†] The motions of the humerus (plate iii. fig. 12—15) are all regularly accompanied by corresponding motions of the scapula, the head of which, excepting in the rotatory motion, generally follows the motion of the humerus. See Barclay *On Muscular Motion*, p. 385. 387. For the deltoides, the biceps, &c. consult the Hæmon, the Gladiator, and the Hercules Farnese.

[‡] The pectoralis in birds is chiefly employed to move the wings in flying. It is very large, (sometimes so large as to outweigh all the other muscles together,) and consists properly of three muscles, the pectoralis major, medius, and minor, which fill the sides of the crest of the sternum. The keel of the sternum, the fork, (merry thought,) and the last ribs give origin to the pectoralis major; its insertion is into a rough, projecting line of the humerus. By depressing that bone, the pectoralis produces the strong and violent motions of the wing, which carry the body forwards in flying. The middle pectoral (or medius) lies under this; and sends its tendon over the junction of the fork, with the clavicle and scapula, as in a pulley, to be inserted in the upper part of the humerus, which bone it elevates. By this contrivance of the pully, the elevator of the wing is placed at the under surface of the body. The third, or lesser pectoral muscle has the same effect with the great pectoral in depressing the wing. Blumenbach's *Manual* by Lawrence, p. 311.

[*] A backward motion of the arm may be of two kinds, according to the motion which has preceded it. 1. If it has been preceded by, and is the continuation of, an *upward* motion, the deltoides and trapezius are assisted by the supraspinatus, infraspinatus, subscapularis, biceps brachii, coracobrachialis, and the clavicular portion of the pectoralis. 2. But if the arm has been previously hanging at the side, or if there has been first a downward movement, previous to the intended one backward and upward; the backward motion, which is to follow in continuation of the other, will be made by the help of the teres major, teres minor, longus, (or long-head of the triceps brachii,) and by the latissimus dorsi.

[†] A motion of the arm forwards may be also of two kinds, according to the motion which it follows. 1. If it succeeds to an upward and backward motion, as after the arm has been raised to strike a heavy blow, the subsequent movement forwards will put into action not only the pectoralis, but the teres major, teres minor, the longus, and the latissimus dorsi. 2. If, on the contrary, it follows a quiescent, pendulous state of the arm, or follows a motion downward and backward, (such as the preparation to throw a cricket-ball in bowling,) the movement of the humerus in throwing will be effected by the muscles which *lift* the arm *forwards*; the deltoides, biceps brachii, subscapularis, trapezius, &c. with the clavicular portion of the pectoralis.

[‡] The teres major forms with the latissimus, the edge of the armpit. Both muscles are well shown in the Fighting Gladiator, which, together with the Laocoon, are the finest illustrations of brachial movement.

[§] Several more are concerned directly or obliquely in these motions. For the sake of illustration let us compare the humerus to the spoke of a carriage-wheel, such as described in Art. 177. Suppose the spoke nearly perpendicular to the ground, with its outer extremity downwards, as must be the case with the humerus while the arm hangs at the side. If the carriage be drawn forward, the outer extremity of the spoke will turn on the axis in a continued curve: first backwards and upwards, then forwards and downwards. Let the carriage be now stopped, and let one side of it be raised from the ground so as to suspend the spoke in question perpendicularly: and let the same motion of the wheel be repeated. It will represent and illustrate, in some degree, a rotatory or conical motion (see the fourth note to Art. 240) of the humerus. This motion, by which the arm is *lifted backwards* from below, is effected by the teres major, the teres minor, the longus, or long head of the triceps brachii, and by the latissimus dorsi, regulated by the deltoides and pectoralis.

Let now the wheel be whirled round in the opposite direction, namely, such as it would take in *backing* the carriage; this motion will also represent a rotatory movement of the humerus, but quite the reverse of the former one. In this movement the humerus will be *lifted forwards*, and consequently be put in motion by the deltoides and trapezius, assisted by the supraspinatus, the infraspinatus, the subscapularis, the biceps brachii, the coraco-brachialis, and the clavicular portion of the pectoralis. Both these motions of the humerus may be familiarly exemplified in the two ways of cracking a whip over or under the hand; and the reader will find innumerable examples from observations of his own, on any athletic exercise of the arm in rowing, swimming, fencing, &c.

Muscles for moving the forearm.

(244.) The four motions of the cubit, or forearm, namely *pronation*, *supination*, *flexion*,* and *extension*, are produced as follows: 1. Pronation, by the pronator teres, (or rotundus,) aided by a muscle entirely concealed, *viz.* pronator quadratus.† 2. Supination by the biceps brachii and the extensor pollicis aiding the supinator brevis, which, like its antagonist the pronator quadratus, is out of view.‡ "The supinator longus cooperates with and moderates alternately the pronators and supinators, bringing the radius to that middle state, which is properly neither pronation nor supination, and performing the office with the greatest force when the arm is extended."§ 3. Flexion is performed by the brachialis internus, the biceps brachii, and the supinator longus.‖ The biceps being an extensor of the humerus, (Art. 243,) will, in this instance, act with more force when the humerus is inflected than when it is extended, *i. e.* lifted forwards or outwards; and will at the same time meet with less resistance from the long or scapular head of the triceps. 4. Extension is the duty of the triceps brachii and of the anconeus. Neither of these muscles is inserted in the radius. The longus, or long head of the triceps, being also a flexor of the humerus, (Art. 243,) will act less forcibly upon the ulna, when the humerus is extended or *lifted forward*, than when it is inflected or *lifted backwards* from below.

Muscles for moving the hand.

(245.) The hand, consisting of the carpus, metacarpus, and phalanges, follows, in the human subject, the motions of pronation and supination above described, which originate in the forearm. The tendons and muscles, therefore, peculiar to the hand may be considered apart from those of pronation and supination, and are usually divided into flexors, extensors,¶ abductors, and adductors.** The flexors and extensors of the *carpus* take their names from their position relatively to the bones of the radius and ulna: the *radiales* on the side nearest the thumb; the *ulnares* on the side nearest the little finger. The flexors lie, as their office must indicate, on a line with the palm; the extensors in a line with the back of the hand. The former, three in number, come out from their joint origin at the inner condyle of the humerus; and run close together along the forearm, beside the supinator longus: *viz.* the flexor radialis, the palmaris, and the flexor ulnaris. The extensor muscles also consist of three: two on the same side with the thumb, *viz.* the extensor carpi radialis longior,* and the extensor radialis brevior; and one on the same side with the little finger, *viz.* the extensor ulnaris.

For the *fingers* the flexors are the perforati and the perforantes, called also the sublimes and profundi, together with the flexor brevis of the thumb. The little finger has, moreover, an inflexion caused by the flexor carpi already mentioned. The extensors are six, *viz.* three extensores pollicis, one of which extends the metacarpal bone of the thumb; the other two its first and second joints: fourthly, the extensor digitorum communis: fifthly, the indicator:† and lastly, the extensor minimi digiti. The *opponens* muscle of the thumb has the important office of applying the thumb with the nicest precision to the tip of any one of the fingers.

It is to the thumb and fingers that the remaining muscles called abductors and adductors belong. These are antagonists to each other, and in the thumb are found on each side of the flexor brevis. The interossei and lumbricales are *ad*ductors of the fingers, assisted sometimes by the perforati and perforantes.‡ On the other hand, when the extensor communis is made to act on all the fingers, they become *ab*ducted, and are seen to diverge like radii from a centre.§

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* In birds, two muscles act as flexors, which hold a situation corresponding to that of pronators. This shows how much inflexion and pronation are connected, the latter being substituted for the former.

† To these Barclay adds the radialis internus, the palmaris longus, and the flexor sublimis, observing that these only act at the commencement of the pronation; and that their power is increased the more according as the hand maintains a greater previous tendency to supination. Also that the power of the sublimis must be further increased in cases where the fingers are extended. Observe that the two pronators (teres and quadratus) are present in the quadrumana and in all carnivorous animals, but are wanting in the chiroptera, ruminantia, and solidungula.

‡ The first of these three acts with the greatest force when the humerus is inflected, (*i. e.* has been drawn backwards from below;) and the last acts with the greatest force when the carpus and thumb are inflected *thenad*, (*i. e.* towards the hollow of the hand.) Barclay *On Muscular Motion*, p 398.

§ Barclay in *loc. cit.* In animals of the dog and cat kind the supinator longus is wanting. The brevis is present. Both are absent in the chiroptera, rodentia, pachydermata, ruminantia, and solidungula. Also both are absent in all birds. (See COMPARATIVE ANATOMY.)

‖ To these are subjoined by Barclay the ulnaris internus, the palmaris longus, the pronator teres, the radialis internus, and the flexor sublimis. These five muscles, he observes, are flexors only to a small extent, and only at the time when the motion commences, before the lever of resistance is shortened. The four last must have their power a little increased when the arm is placed in a state of supination, and when, consequently, the biceps is somewhat relaxed.

¶ No other but the extensor digitorum communis is common to Man and all the quadrupeds. To extend the fore pastern, the horse has two extensores proprii on the side of the extensor communis. They are assisted by a third extensor between the communis and the extensor of the pastern. The extensor proprius indicis is wanting in the rodentia, ruminantia, and solidungula. The genus felis, canis, and ursa, and the genus lepus have the extensor longus pollicis, but want the extensor brevis. The ruminantia and solidungula have both.

** The short muscles of the hand which produce flexion, abduction, adduction, and opposition, are altogether wanting in the lower animals. The muscles of the lower animals are generally less in number than those of Man. The deficiency is most frequent among the inferior orders of *Mammalia*, and still more in birds. Muscular varieties occur chiefly in the organs of locomotion. Throughout the entire class of birds the following muscles are absent, and may here be mentioned together. The diaphragm, recti abdominis, pyramidales, the dorsal muscles of the spine, splenius, brachialis externus, or third head of the triceps, the supinator of the forearm or wing, and short muscles of the hand and fingers, as already stated; quadratus lumborum, psoas parvus and magnus, iliacus internus, obturator externus, and extensor longus pollicis pedis.

* The peculiar projection of this muscle from under the supinator longus may be well studied both from the antique and from the Cartoons of Raffaelle.

† The indicator assists the extensor communis in enabling all the joints of the forefinger to point at any thing. Hence its name.

‡ Hence it happens that during flexion, the fingers can never be separated so widely as during extension. On the different appearances of the muscles in the hand and arm in the action of opening or shutting the hand, see Da Vinci, *Trattato della Pittura*, cap. 176. The action of the flexors in bending the fingers gives an enlarged appearance to the wrist, observable in the left hand of the Apollo and the right hand of the Gladiator.

§ The thumb in the simiæ is small, short, and weak; the other fingers are elongated and slender. Other animals which have fingers sufficiently long and movable for seizing and grasping objects, are obliged, from want of a separate thumb, to hold them by means of the two forepaws; as the squirrel, rat, oposum, &c.; those, moreover, which are obliged to rest their body on the forefeet, as the dog and cat, can only hold objects by fixing them between the paw and the ground. Lastly, such as have the fingers united by the integuments, or enclosed in hoofs, lose all power of prehension. We advise every artist who loves truth of outline to attend a dissection of the human arm and hand, as well as of the parts analogous in the forearm, claws, hoofs, paws, &c. of animals generally. He

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(246.) THE REGION OF THE ABDOMEN was, lastly, to come under notice. For its posterior boundaries in the human subject we proposed the five lower dorsal and the five lumbar vertebræ,* increasing in breadth and thickness as they descend, and resting on the os sacrum as a column upon its base; from which are stretched to the right and left the strong bony arches of the ilium, one to the top of each femur. Five ribs, called false ribs, protect each side,† while a third arch of bone in front (the ossa pubis) joining the other two lateral or iliac arches, and below it the two angular bones (ossa ischii) on which the figure rests when sitting, complete the abdominal outline of the skeleton. In front and at the sides this outline is filled up with the abdominal muscles and viscera. The bones throughout this region that chiefly deserve the artist's attention are, 1. The bones of the spinal column just alluded to. Like the vertebræ of the neck this bony chain of the loins is formed for gradually bending itself into a great variety of curves.‡ 2. The pelvis, so called from some resemblance to a basin.* It comprises the several bones already named which are partly cemented into one,† *viz.* the os sacrum,‡ the ossa ilium, the ossa pubis, and the ossa ischii.§ 3.

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will find, indeed, respecting most forms, functions, and relative positions throughout the muscular economy, that one hour in the dissecting room will sometimes explain more than he could learn from a year of study among folios of careful description and most elaborate comment. Respecting the muscles of the human forearm, we only observe, in conclusion, that they are never strongly marked, unless the hand is engaged in grasping with force any object.

* The lumbar vertebræ vary considerably in number. The elephant has only three; the camel seven; the horse has six, the ass five; mules have generally six, but sometimes only five. Most quadrupeds have the processes of these vertebræ turned forwards; in the ape they are in their ordinary position turned upwards. The transverse processes are remarkably large in many *ruminantia*, as also in the hare. Blumenbach's *Manual* by Lawrence, p. 43. In birds, that part of the spine which belongs to the trunk is short and rigid, and has no true lumbar vertebræ. *Ibid.* p. 61.

† The parts of the body which contain the principal organs for respiration and circulation are placed in the chest, strongly guarded by the upper ribs, by the sternum, and upper dorsal vertebræ. But the parts placed below (or in quadrupeds *behind*) these, and composed of the abdomen, the viscera, and loins, have no bony enclosure; and are undefended, except on one side towards the backbone, by other ribs, termed false ribs, (of these the horse has ten,) which take the same direction as the true, but become shorter as they approach the loins. A reason for this arrangement appears to be, that the functions of the bowels and abdominal parts will be performed more freely without this external guard; but chiefly, that greater room and play may be allowed for motion throughout the various turnings and bendings necessary to balance the rest of the body, or sustain it in the easiest and most convenient position. The want of motion in the back of birds (their dorsal vertebræ have the spinous and even the transverse processes often anchylosed) is compensated by a larger number, and by greater mobility of vertebræ in the neck. Of these latter, to quote a few instances, the raven has twelve, the cock thirteen, the ostrich eighteen, the stork nineteen, and the swan twenty-three. Four or five of the upper cervical vertebræ only have power to bend forwards, while the lower ones are confined to flexion backwards. This causes the double curvature resembling the letter S in the neck of a bird. The great mobility of the neck enables birds to touch every point of their own body with the bill, and thus supply the want of a prehensile faculty in their upper limbs. In proportion as their neck is movable their spine or backbone will be found consolidated. Steadiness is thus given to the trunk in the violent exertion required for flying. Birds which do not fly, as the ostrich and the cassowary, have a movable spinal column.

‡ Each of the twenty-four bones of the spine from the human coccyx upwards to the occiput is attached to its neighbour by means of four projecting parts; two at its upper, and two at its lower side, called the superior and inferior oblique processes. The former two act as supports for the two similar projections in the next vertebra above. The two latter rest upon or overlap the two adjacent projections in the next vertebra beneath them. Besides this mode of union these vertebræ are held together by strong ligaments extending in great variety over the parts where the vertebræ are contiguous; not binding them so tightly as to prevent easy motion, but preserving them from separation, except by such force as would break the bone itself. The rounded part of the column, which lies next the interior of the thorax and abdomen is called the body of the vertebra. Each vertebra, besides its body or ring of bone and the projecting parts already mentioned, which unite it with its neighbours, has other projections also to which muscles are attached turning the vertebræ to the right or left, backwards, forwards, or laterally. These have the name of processes. Those behind down the middle of the spine are called spinous processes. Those on each side are called the transverse processes. The course of the spinous processes is more or less distinctly visible in the living subject according to the bendings of the back. To steady the back in bending is the use of the ligaments that were mentioned. "The vertebræ," says Paley, "by means of their processes and projections, and of the articulations which some of these form with one another at their extremities, are so locked in and confined, as to maintain, in what are called the bodies, or broad surfaces of the bones, the relative position nearly unaltered, and to throw the change and the pressure produced by flexion, almost entirely upon the intervening cartilages, the springiness and yielding nature of whose substance admits of all the motion which is necessary to be performed upon them without any chasm being produced by a separation of the parts. I say, of all the motion which is necessary; for although we bend our backs to every degree almost of inclination, the motion of each vertebra is very small; such is the advantage which we receive from the chain being composed of so many links; the spine of so many bones. Had it consisted of three or four bones only, in bending the body the spinal marrow must have been bruised at every angle. The reader need not be told that these intervening cartilages are gristles; and he may see them in perfection in a loin of veal. Their form also favours the same intention. They are thicker before than behind; so that when we stoop forward, the compressible substance of the cartilage yielding in its thicker and anterior part to the force which squeezes it, brings the surfaces of the adjoining vertebræ nearer to the being parallel with one another than they were before, instead of increasing the inclination of their planes, which must have occasioned a fissure or opening between them." Paley, *Natural Theology*, 8vo. 1807, p. 110. A new edition of this Work is promised under the scientific and indefatigable auspices of Lord Brougham.

* Blumenbach observes that "no animal but Man has properly a pelvis, because in no instance have the bones of this part that basin-like appearance when united, which belongs to the human subject. In the elephant, horse, &c. the length of the symphysis pubis detracts from the resemblance to a basin." Perhaps the most generally applicable illustration for this part of the animal structure may be made by regarding it as the lower or hinder portion of a two-wheeled or four-wheeled carriage. And in this vehicle the weight to be sustained is either placed upon and within it as in the case of Man; or is suspended from it as in the case of birds and quadrupeds. The pelvic esseda, or currus on which the human trunk is poised and in which it is carried, may be said to move upon two wheels the spokes of which answer to the peculiar position and rotatory movements of the femora. The quadruped, on the other hand, may be said to form a plaustrum, having four wheels. But then this waggon (to make the comparison a proper one) must not have the load placed within it or upon it, but must be that kind of machine used very commonly for moving heavy beams or logs of timber which are suspended from a horizontal pole as from a spine. This suspension occurs also among birds when they stand or walk, except that their bodies may be said to hang from a pole or spine which rests upon two wheels only. See last note to Art. 243.

† The os sacrum and ossa ilium are not altogether anchylosed, except in very old subjects; generally, they are united by articulations and cartilages. In birds the ossa ilium extend upwards to the region of the thorax.

‡ The os coccygis is prolonged, so as to form the tail of quadrupeds; and consists therefore, in many cases, of a great number of vertebræ. Blumenbach, p. 44.

§ The two last-named pairs do not show themselves prominently from under their muscles so as to be remarkable in the life. But the os sacrum is important as containing and marking in most animals the extreme intersection of the mesial plane, (Art. 234,) and also the extreme point at the bottom of the back. The markings, too, of the upper parts in the arches of the ossa illi, showing the course of what is called Poupart's or Fallopius's ligament, are distinctly visible in the human subject, as also in quadrupeds; near

The os coccygis, which though of small importance to the artist in the human subject, is in lower animals and in quadrupeds actively conspicuous. It contains the tail, one of the most characteristic features for animal expression, consisting of more or less vertebræ, with various degrees of strength and mobility, according to the wants and habits of the animal.[*] 4. The supporting limbs in the abdominal region comprise the hinder legs of quadrupeds: and in Man the *inferior extremities*, so called to distinguish them from the two other limbs appended to the thorax, and called the *superior extremities*. Between these two thoracic limbs and those two supporters of the abdomen there are several points of analogy. Each superior extremity consists of four parts; each inferior also of four that correspond to them. First the ball and socket joint of the shoulder (at the union of the clavicle and scapula) answers to the ball and socket joint of the round head of the femur, (at the junction of the os pubis with the os ilium,) only that the latter socket, called the acetabulum,[†] is deeper and larger than the glenoid socket or cavity. Again, the humerus with its hinge-joint at the elbow, answers to the femur[‡] with its hinge-joint at the knee. Thirdly, the part composed of the radius and ulna of the fore-arm answers to the tibia and fibula of the leg;[*] and fourthly, the carpus, metacarpus, and phalanges of the fingers answer to the tarsus, metatarsus,[†] and phalanges of the toes.[‡]

Points, lines, and planes, for determining their position.

(247.) We now proceed as before, according to what was suggested in Art. 220, to devise for the region of the abdomen certain *imaginary points, lines, or planes* for determining the relative position of the bones, as seen from any point of view. There are, in the human pelvis, three fixed points, which being joined by three straight lines will always form a triangle, the plane of which having a known or determinate inclination either to the horizontal or any other plane is easily found.

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the croup, for example, of a horse, or ox, the spines of the ossa ilii stand up on each side of the hinder extremity of the backbone.

[*] The tail in mammalia consists of a series of vertebræ, being a prolongation of the os coccygis successively decreasing and moved by no less than eight pairs of muscles, of which the action is threefold; one for extending and elevating the tail; a second for inflecting or depressing it; and a third by which it beats or lashes the sides of the animal. These motions in succession or combination form others more complex; so that the tail may be twisted on its axis, or turned in a spiral direction.

[†] "The joint at the shoulder compared with the joint at the hip, though both are ball and socket joints, discovers a difference in their form and proportions well suited to the different offices which the limbs have to execute. The cup or socket at the shoulder is much shallower and flatter than it is at the hip, and is also in part formed of cartilage set round the top of the cup. The socket into which the head of the thigh-bone is inserted, is deeper and made of more solid materials. This agrees with the duties assigned to each part. The arm is an instrument of motion principally, if not solely. Accordingly, the shallowness of the socket at the shoulder, and the yieldingness of the cartilaginous substance with which its edge is set round, and which, in fact, composes a considerable part of its concavity, are excellently adapted for the allowance of a free motion and a wide range, both which the arm requires. Whereas, the lower limb forming a part of the column of the body, as well as to be the means of its locomotion, firmness was to be consulted as well as action. With a capacity for motion in all directions, indeed, as at the shoulder, but not in any direction to the same extent as in the arm, was to be united stability or resistance to dislocation. Hence the deeper excavation of the socket, and the presence of a less proportion of cartilage upon the edge."—Paley, *Natural Theology*, p. 126.

The length of the neck in birds increases generally in proportion to that of the legs, but in a much greater proportion among aquatic birds, since they have to seek their food below the surface of the water in which they swim. The number of cervical links or vertebræ of the neck varies from ten to twenty-three. That of the dorsal from seven to eleven. From hence they are consolidated into one piece with the os innominatum. The tail has from seven to nine pieces.

[‡] The femur of the other mammalia follows, in its general figure and parts, the type of that of the human frame. But it is not arched as in the human subject: it possesses scarcely any neck, and the great trochanter ascends beyond the head of the bone. The femur of most quadrupeds is much shorter than the tibia, and hence it hardly projects from the abdomen. In some few, as the bear, the femur is longer; also in some apes, *viz*. the ourang-outang, in which, as in several other apes and baboons, the bones of the arm and forearm are surprisingly longer than those of the thigh and leg. Some, as the elephant, have no ligamentum teres, consequently there is no impression made on the head of the thigh bone. The length of the femur depends on that of the metatarsus, and bears an inverse ratio to the length of that part. Blumenbach, *Manual*, p. 53. The femur of birds is provided with one trochanter only.

[*] The pecora want the fibula universally. In some simiæ the leg and forearm exceed the thigh and arm. In other animals, although there are some varieties, the leg is generally longer than the thigh. The fibula is behind the tibia in many animals, as the dog and the rodentia. It is consolidated to that bone at its lower end, in the mole and in the rat. It exists only as a small styloid bone in the horse, and becomes in an old animal anchylosed to the tibia. *Ibid.*

In the rhinoceros, elephant, and hog, the fibula is flattened and united to the whole length of the tibia. In ruminant animals, its place is supplied by a small excrescence of bone on the outer margin of the astragulus below the tibia, and forming the external or fibular ankle.

[†] The os calcis in the *rodentia*, stands out considerably backwards. The os scaphoides, consisting of two parts, forms a tubercle on the sole. The scaphoid of the hog is assisted by three cuneiform bones, and beneath the first the rudiment of a great toe. These animals have all the same number of toes as of metatarsal bones. In the *ruminantia* the os cuboides and os schaphoides are distinct bones only in the camel; in all other ruminants they are united in one. In the *solidungula*, the scaphoid and cuboid are separate. The tarsus of the horse is composed of six bones, in common language called the *hock*.

The fibula, in birds, forms a thin slip adhering to the tibia as far down as the middle of the latter. The latter, at its tarsal extremity, terminates in two condyles with a pulley-shaped groove between them. Attached to it, in place of the tarsus and metatarsus, stands a single bone of considerable length, and having three processes, to which are attached the bones of the three anterior toes, with a marginal attachment for the bone of the great toe. The metatarsal of the ostrich is confined to only two processes, that being the number of toes in that bird. An excrescence of horny matter, commonly called the spur, is attached above the great toe to the metatarsal of several gallinaceous birds.

In the ruminantia and solidungula three metatarsal bones are united into a single one, called the cannon bone. The structure of the metatarsus, as that of the horse, is the same with the structure of the metacarpus. In the pachydermata, as the pig and elephant, the metatarsal bones, where they join the tarsus, have a flat surface, and at their other extremity a round tubercle with a prominent line below in the middle of the bone. The elephant has five perfect toes; the hog four. Ruminantia have two perfect toes upon one metatarsal bone; and two small toes attached behind its base. The solidungula have one perfect toe and two imperfect, which are reduced to a single styloid bone; they are distinguished by supporting themselves in walking only upon the last phalanx to which the hoof, analogous to the human nail, is affixed. The only part of the foot in the ruminantia and solidungula which is applied to the ground, is that unguinal phalanx. In other animals, as the dog and the cat, the body is supported upon all the phalanges of the toes. The elongation of the metatarsus removes the os calcis of the horse and ruminantia at such a distance from the toe that it is placed midway between the trunk and hoof.

[‡] Three positions at the upper part of the femur require careful attention; that of its round head already mentioned on which it turns; and that of two prominences for the attachment of important muscles, *viz*. the greater and the less trochanter, with a foss or groove situated posteriorly between them. The marking of the patella at the knee and of the crural extremities at the ankles are conspicuous; also the os calcis and astragalus together with the arches of the foot.

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(Art. 208.) By the term fixed is meant that notwithstanding any change in the position of the body, they never in one and the same subject change their distance from each other. The three fixed points of the pelvis which we conceive most generally available to the draughtsman are what we will term the *sacral* point and the two *acetabular* points. The sacral is a point in the sacrum under the centre of the lowest vertebra of the back. The right and left acetabular points are close to the centres of motion within the right and left acetabula. The sides of this triangle may be further considered as containing or measuring the spans of the three arches into which we divided the pelvis. (Art. 246.)

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We will denominate therefore the three lines that make the triangle—the line of the right iliac arch; the line of the left iliac arch; and the acetabular line,* or line of the pubic arch. For example, in the triangle A B C, (plate iii. fig. 16,) the point B is the sacral point; A the right acetabular, C the left acetabular point; A C the acetabular line; B A the line of the right iliac arch; B C the line of the left iliac arch.

ro-pubic , viz. the rsection he plane he pelvic ngle i the me- plane.

(248.) A straight line B D from the sacral point B to the centre D of the acetabular line is the sacro-pubic line. When the figure is erect, balanced equally on both legs, this line is nearly perpendicular to the horizon. It is the line of intersection of the mesial plane of the pelvis with the plane of the pelvic triangle A B C; in the same manner as the sterno-dorsal line (Art. 224) is the line of intersection for the mesial plane of the thorax with the supercostal plane; or, as in the region of the head, (Art. 226,) the head's axis is the intersection of the mesial and coronal planes, and the occipital line the intersection of the mesial plane with the maxillary plane.†

(249.) The position of the limbs in the abdominal region may be ascertained in the same manner as that of the humerus and forearm, (Art. 238,) and with less difficulty, because the points A and C (plate iii. fig. 17,) are fixed; (Art. 247;) whereas the points of the shoulders must continually change their relative position according to the motions of each clavicle. A line from either of the acetabular points A or C to a point between the condyles of the femur, may be called the line of the femur, or the *femoral* line. Again, from between the condyles of the femur a line to the top of the astragalus, where the latter affords a pedestal to the column of the tibia, may be called the line of the leg, or *crural* line.‡ From the supporting point at the lower extremity of the crural line, another line (in the human foot) may be drawn to what, in common speech, is called the ball of the great toe; but is, in fact, the junction of the metacarpal of that toe with its first phalanx. This line will be in the direction of one of the arches formed by the bones of the tarsus for supporting the human body: this line therefore may be termed the line of the inner arch of the foot. Another arch extends also from the heel to where the metatarsal of the little toe joins the tarsus.*

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l line.

Line of the inner and outer arch of the foot.

Motions of bones in the region of the abdomen.

(250.) *The motions of which the bones* in the region of the abdomen *are capable* come next under consideration. The motions of the bottom of the back, or lumbar vertebræ, are various; and its curves, like those of the neck, are by no means easily ascertainable for the pencil. The position of the pelvis relatively to the rest of the animal frame is the more difficult to determine in proportion to the mobility of the lumbar vertebræ.†

(251.) The motion of the femur‡ resembles that of

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* The length of the acetabular line, or distance between the acetabular points, is greater in the female.

† These lines, the axis of the head, the occipital line, the sterno-dorsal, and the sacro-pubic come under the general terms of *mesial lines of intersection*. They are in every case the intersection of two planes at right angles with each other. The mesial plane, therefore, and the plane of the pelvic triangle will always intersect each other at right angles, just as the coronal and maxillary (Art. 226) and supercostal planes are always at right angles with the respective mesial planes of the head and thorax.

‡ Allowance, in all cases, must be made for the different degrees of compression in the cartilages at the joints of any limb, or at the articulations of the several bones. In proportion as the cartilaginous spring which divides any two bones is compressed, their length will be diminished. This compressibility is greater after fatigue, or in sickness, than when the powers of animal life are vigorous and fresh. Thus men are taller when they rise after sleep than if measured after a day's labour, when the elasticity of the cartilages has been reduced. Another yet more remarkable variation in the length of the limbs, and consequently in the lines of the humerus, forearm, and hand, as well as in the femoral, crural, and metatarsal intervals, arises from the nature and form of the joints themselves. A hinge-joint, when it bends, must leave, on the side opposite that towards which it bends, a greater or less space; greater as the angle becomes more acute, and less as the angle enlarges. Of this any person may be made sensible who can open or shut a door, or swing a gate. Hence it happens that the length of such limbs as have hinge-joints is shorter when they are extended than when they are bent. Of the human arm Da Vinci reckons that it loses or gains one-eighth in its length according as it is stretched out or drawn in by inflection. Also in the foot, that part called the instep, or the interval between the great toe and the tibia, lessens as the tibia rolls forward on the astragalus by the action of the tibialis anticus muscle; on the other hand, the interval increases when the heel is raised, and the os calcis makes with the tibia an acuter angle. Da Vinci, *Trattato della Pittura*, c. 174, and c. 177.

* Suppose the sole of the foot planted firmly on the ground; I K (plate iii. fig. 17.) will be the place of the os calcis, K H will be the line of the inside arch of the foot, and the line I G will show the direction of the supporting arch under the malleolus externus, or outer ankle, extending from I, under the os calcis, to G (the junction of G L, the metatarsal of the little toe with the tarsus;) I G, therefore, may be termed the line of the outer arch of the foot: under G H is a third arch supported on the side of L H by all the toes. When the figure stands on tiptoe, the metatarsals along the line L H form five hinges, on which to turn the whole superincumbent frame of the body. The observant reader will not need to be informed, that this occasional position of the human foot supporting the body on its toes, is analogous to the usual position of the hinder legs and feet of quadrupeds. (Notes to Art. 246.) The outer ankle is lower than the inner one: upon the accurate outline of these malleoli, as well as upon the right position of the carpal extremities of the radius and ulna, must depend much of the expression of which the hands and feet are so beautifully capable.

From the nature of the hinge-joint at the knee, and at the lower extremity of the tibia, it follows, that the femoral and crural lines, together with a line through the foot parallel to the line of its inner arch, will be always in the same plane. Consequently, if the acetabular point be given, as well as the length of the femoral and crural lines, and also the vanishing line of the plane that contains them, they may be represented making, under any aspect, any required angle with each other. So also the line of the outer arch of the foot may be represented making any required angle with the crural line.

† The method which was suggested (Art. 231) for measuring the extent of the conical motion of the neck may here be again serviceable towards outline of the human subject. Let the two points at the two extremities of the curve be regarded as alternately the apices of various cones. In the present case let those two points be the centre of the seventh dorsal vertebra (Art. 235) and the sacral point. (Art. 247.) If the sacral point be stationary, then the seventh vertebra of the back may be considered as describing the base of a cone, of which the sacral point is the apex; and of which the altitude will be inversely as that base. The upper part of the body will, in this instance, be entirely supported upon the lower extremities. But suppose this instance reversed. Suppose the thorax fixed as that of a sailor descending by a rope, the weight of whose abdomen and body are suspended from his upper extremities: the sacral point, in this latter instance, may describe in its turn the base of a cone on similar conditions with that described before by the seventh vertebra which now takes the part of apex.

‡ In Man the femur is placed on the same line with the trunk of

the humerus, but is less varied; the arms and hands have motions fitting them more particularly for action; their business is chiefly *manual;* whereas the legs and feet, being chiefly intended for supports of the body, have not the facilities of changing their position so quickly, or in so many ways, as the arms and hands. The tibia therefore and fibula have no pronation nor supination. (Art. 240. 244.) The leg, indeed, may be rolled, and the foot turned inwards or outwards till the heel appears in front, but this is done through the rotatory motion of the round head of the femur.[*]

Action of muscles in the region of the abdomen.

Muscles for moving the trunk.

(252.) The *muscles* and their attachments in the region of the abdomen which require the artist's careful examination, are, (in the human subject,) 1. The *obliqui externi.*[†] 2. The *obliqui interni.*[‡] 3. The *transversales abdominis*, although covered by both the former, and therefore less apparent, are yet necessary to be here remarked upon, since their junction (at the edge of the rectus) with the tendons of the obliqui abdominis, forms what is called the *linea semilunaris.* The transversalis supports and compresses the viscera. 4. The *rectus abdominis.*[§] 5. The student will remark several *tendinous ligaments.*[‖] 6. The *pyramidalis.*[¶] All the above muscles have a share together with the *pectorales* (see region of the thorax) and *psoæ magni* (see Art. 254) in bending the trunk *forwards.*

(253.) For the backward inflection of the trunk, we reckon. 1. The *trapezii.*[*] 2. The *latissimi dorsi.*[†] 3. The *sacro lumbales.*[‡] 4. The *longissimi dorsi.*[§] 5. The *serrati postici.* One pair called superiores, employed for elevating; another, the inferiores, for depressing the ribs. These two pair of muscles assist the backward inflection of the trunk. The former pair arises from the three lower vertebræ of the neck to be inserted by distinct fleshy slips into each of the five upper ribs. The latter pair arises from the spinous processes of the two latter vertebræ of the back, and from the same parts of the three upper vertebræ of the loins by means of a fascia called the fascia lumborum.[‖] The serratus posticus inferior is inserted into the lower edge of the four lowest ribs.[¶]

Muscles for moving the femur.

(254.) The muscles for the five motions of the human femur.[**] 1. To extend or stretch it forwards; 2. to

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the body; in other animals it always forms an angle, and sometimes a very acute angle with the spine.

[*] It is to multiply this variety of femoral motions that the head of the femur is provided with a neck extending nearly two inches from the acetabulum, and making an angle (downwards) of about 38 degrees with the remainder of the bone of the thigh. The advantages of this kind of projection we have already remarked upon in Art. 177, for supporting the weight of a carriage. We may conclude universally respecting the motion of the several bones in the limbs of the abdomen, that it includes flexion and extension; and that it superadds abduction and adduction, with a certain degree of rotation for turning the toes inwards or outwards; and we must observe, that from the great toe being destitute of an opponens muscle like that of the thumb, the foot has no prehensile powers at all to be compared with those of the hand.

[†] Called *descendentes*, from their spreading obliquely downwards out of their serrated origin in the eight inferior ribs between the digitations of the serratus magnus anticus, (referred to in the last note to Art. 242 as belonging to the thorax,) in order to insertion into the ensiform cartilage of the sternum, into the linea alba, along the whole of its length, and into the forepart of the spine of the ilium. The obliqui draw down the ribs in expiration, bend the trunk forwards when both muscles act, or bend it obliquely to one side when one acts; raise also the pelvis obliquely when the ribs are fixed, and compress the viscera.

[‡] Called *interni* from lying under the former muscles, and called *ascendentes* from their *rising*, anteriorly as well as posteriorly, out of the whole length of the spine of the ilium, and out of the upper part of Poupart's ligament, and out of the fascia of the loins, to be *inserted upward* into the cartilages of the five inferior ribs, into the ensiform cartilage of the sternum, and into the linea alba: the obliqui interni assist the before-named muscle. Observe, however, that each internal oblique bends the body in the same direction as the external oblique of the opposite side.

[§] Originating from the middle of the pubis, and extending directly upwards to its insertion into the ensiform cartilage, and into the fifth, sixth, and seventh ribs: it compresses the forepart of the abdomen, bends the trunk directly forwards, or raises the pelvis. Between the two recti abdominis is a central tendon, called the linea alba, conspicuous in the Mercury, and in antique figures generally.

E. gr. *Poupart's* ligament, attached at one end to the spine of the os pubis, and at the other to the anterior of the spine of the ilium; likewise the *linea alba*, which comes from the sternum towards the symphysis pubis, dividing, like the intersection of the mesial plane, the right side of the abdomen from the left, and composed of the united tendons of the obliqui and transversalis. Lastly, the *lineæ transversæ* must be noticed, being three tendinous intersections of the rectus shining through the strong sheath which encloses it, and extending transversely across the linea alba to the lineæ semilunares on each side; the middle linea transversa crosses the umbilicus, or navel. The liniæ transversæ are remarkable in the Hercules Farnese and the Torso.

[¶] This muscle originates from the pelvis, and is inserted into the linea alba immediately below the lowest of the lineæ transversæ.

[*] Partly situated in the region of the head and thorax, they have origin from the occiput and five superior cervical vertebræ at the ligamentum nuchæ along the spinous processes, as well as from the two remaining vertebræ of the neck, and from the spinous processes of all the dorsal vertebræ, are inserted into the hinder part of the clavicle, and into the acromion, and into the spine of the scapula. The various origins of the trapezii along the line of the vertebral processes serve to explain the extraordinary variety of action upon the shoulder performed by the fibres of this muscle. The joint action of all draws the upper part of the body backwards.

[†] They have origin in four or five directions; one from the spinous processes of the sacrum; one from those of the lumbar vertebræ; one from those of the six or seven inferior dorsal vertebræ. The latissimus originates also from the back part of the spine of the ilium, and from the extremities of the three inferior false ribs, by distinct fleshy digitations intermixing with the digitations of the obliquus externus. (Art. 252.) The latissimus, passing over the inferior angle of the scapula, receives often from thence some attaching fibres, and passes to be inserted into the humerus at the inner part of the bicipital groove (Art. 233) before the insertion of the teres major. This muscle is very forcibly given in the Gladiator, and the Hercules Farnese.

[‡] They arise out of the back part of the sacrum and its spinous processes; also out of the back of the spine of the ilium; also out of the lumbar vertebræ, *viz.* from the roots of their transverse processes, and from their spinous processes. The sacro lumbalis is inserted into all the ribs near their angles by long and thin tendons.

[§] They arise in common with the last pair of muscles from the same parts of the sacrum and lumbar vertebræ. The longissimus is inserted into all the ribs except the two last, and sends tendinous slips into the transverse processes of the fourth, fifth, and sixth cervical vertebræ. In ascending, it adheres to the transverse processes of all the dorsal vertebræ. Its office singly, is to bend the body sideways, but in conjunction with its fellow, its office is to extend the vertebræ, and thus erect the body. Although the two last-mentioned pairs of muscles, together with the splenius colli, (see region of the neck,) are entirely covered by the trapezii and latissimi dorsi, yet their shape and action will be often found sufficiently marked and visible in the living subject.

[‖] The fascia lumborum is formed by the latissimus dorsi and the obliquus internus abdominis uniting with the tendon of the serratus posticus inferior.

[¶] To these muscles for backward inflection Barclay adds the rhomboidei majores, the spinales and semispinales dorsi, the multifidi spinæ, intertransversarii dorsi et lumborum, and the quadrati lumborum. Of the two last, he says, that he has enumerated them because they are "dorsad (behind) the centre of motion, and, accordingly, relaxed in the dead body when the trunk is inflected in the dorsal (backward) direction."

[**] The situation, generally, of the femoral muscles is thus described. The tensor vaginæ femoris and sartorius will be seen attached above to the anterior spine of the ilium; along the front of the femur may also be observed the rectus femoris. On the outer side is the vastus externus, and on the inner side, along the edge of the rectus, is the vastus internus. Immediately on the inner side of the sartorius

bend it backwards; 3. to draw it outwards from the side by *ab*duction; 4. to draw it inwards towards the opposite femur by *ad*duction; 5. to turn the toes by rotation[*] are employed as follows:

1. *Extension* is the duty of the *gluteus magnus*,[†] which originating from the back of the spine of the ilium, from inside of the sacrum, and from the coccyx, and taking hold of the ligaments between the sacrum and ischium, is inserted into the upper and outer part of the linea aspera. For the same office, the *gluteus medius*[‡] arises from the spine of the ilium and from the external surface of that bone to be inserted into the upper and outer part of the trochanter major. Another extensor is the long head of the *biceps cruris*[§] arising in common with a muscle called the semitendinosus from the upper and back part of the tuberosity of the ischium. Its short head arises from near the middle of the linea aspera. The two heads are continued separately downwards till they unite a little above the knee-joint and terminate in a strong tendon passing at the outside of the knee to be inserted into the head of the fibula. The remaining muscles to be mentioned for extension of the femur are, the *semitendinosus*, the *semimembranosus*, and the *adductor magnus*.[‖]

2. For *flexion*, or bending the femur *backwards*, the muscles to be noticed in Painting are next to be enumerated. The *sartorius*[*] arises by short tendinous fibres anteriorly from the top of the spine of the ilium, and descending thence obliquely (about two inches in breadth) across the femur to the knee behind the inner condyle, terminates in a flat tendon which is inserted into the inner side of the tibia, four or five fingers breadth below the knee-joint. The *gracilis* arises in a thin tendon near the symphysis pubis, and forms, as its name implies, a slender muscle. It passes down the inside of the femur to the knee, and is inserted by a tendon into the inner side of the tibia between the insertion of the sartorius and of the semitendinosus. The *tensor vaginæ femoris* arises by a short tendon from the outer part of the spine of the ilium near the origin of the sartorius and between that and the anterior fibres of the gluteus medius. It descends a little way along the inside of the thigh to a short distance below the trochanter major, and is inserted into a folding of the aponeurosis or fascia lata of the thigh. (Art. 259.) The *pectineus*, or *pectinalis*,[†] arises fleshy from the upper and forepart of the os pubis, and descending (a broad flat muscle) behind the femur is inserted by a short flat tendon into the upper part of the linea aspera a little below the trochanter minor. The *triceps femoris*[‡] comprises three distinct muscles called *adductores*, one of which, the adductor magnus, is only partly concerned in flexion of the femur, being sometimes partly employed, as was seen above, in extension. Its origin and insertion have been stated. (See note at the bottom of the last column.) The *flexor* portion of the adductor *magnus* is that which arises from the crus or ramus of the ischium. The adductor *longus* originates from the upper and forepart of the os pubis, and from the neighbouring cartilaginous ligament; the adductor *brevis* from the os pubis near the symphysis. The former is inserted into the middle of the linea aspera; the latter into the upper part of the linea aspera. The *psoas magnus* arises laterally from the bodies of the four upper vertebræ of the loins, and from their transverse processes, and also from the lowest vertebra of the back. The *iliacus internus* arises from the concave surface within the ilium and from its outer edge, and passing over the ilium near the os pubis is inserted with the psoas magnus by a tendon into the trochanter minor. These two last-named muscles form the thick fleshy mass which is seen

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above is the psoas magnus and iliacus internus descending together in one mass beneath Poupart's ligament into the hollow of the thigh. Next to these is the pectinalis running obliquely downwards from the pubis to the upper part of the femur. The inside is occupied by a large mass of muscle, consisting of the triceps adductor femoris, and a long slender muscle, the gracilis. See Simpson, *Anatomy of the Bones and Muscles designed for the Use of Artists*, part ii. p. 114. For a popular description of these muscles in the Horse, see *Library of Useful Knowledge*, Farmers' Series, part ix. p. 259, 260. describing those of the femoral or hinder extremities. Those of the fore-quarters will be found in the same Treatise, p. 228.

[*] There is a rotatory movement of the femur similar to though not so extensive as that of the humerus. (Art. 243.) This is performed by the combined or successive action of the muscles employed in the four other motions here stated.

[†] The gluteus maximus, (or magnus,) which is the largest muscle of the human body, is so small and insignificant in other animals that it may be said not to exist. It extends the pelvis on the femora of the human subject in standing, and assisted by the other two glutei maintains that part in a state of equilibrium on the lower extremity, which rests on the ground, while the other is carried forwards in progression. The true office, therefore, of these important muscles does not consist, as it is usually represented in the common anatomical works, in moving the femora on the pelvis, but in that of fixing the pelvis on the femora, and of maintaining it in an erect position. Blumenbach, *Manual*, p. 308.

[‡] The buttock, in quadrupeds, is formed of the gluteus medius and minor. In the horse, for example, though the gluteus magnus has chiefly the character of a slight aponeurosis, the gluteus medius is distinguished by remarkable strength, which in connection with some other muscles, particularly the gemellus, enables the animal to extend the hind leg suddenly and with astonishing force in kicking. p. 311.

[§] This muscle in all quadrupeds is not properly a biceps, but a triceps, namely, with a single head, having one origin only. It arises from the ischium. It is the *vastus longus* of the horse and dog.

[‖] The first of these is for about two or three inches, connected, as above stated, with the biceps. It ascends on the inside of the femur to form a thick belly, from which a long, round tendon runs behind the inner condyle to be inserted immediately below the tuberosity of the superior end of the tibia. The next, the *semimembranosus*, arises near the muscle last named, only in front of it, from the upper part of the tuberosity of the ischium, and proceeds obliquely down the femur beneath the semitendinosus to be inserted into the upper and inner part of the head of the tibia. This muscle with the semitendinosus forms the inner hamstring. The last, the *adductor magnus*, is one of three distinct muscles sometimes included altogether under one term, *triceps* cruris, or triceps femoris. The adductor magnus originates from the edge of the os pubis near the symphysis, and thence continues to rise from the ascending ramus and tuberosity of the ischium. That part of it which arises out of the tuberosity of the ischium is the part here required for extending the femur. The whole passes behind the femur to be inserted into the entire length of the linea aspera and into the internal condyle.

Other muscles named by Barclay for extension of the femur are the pyriformis, the obturator internus, the gemini, and the quadratus femoris, all concealed under the gluteus magnus.

[*] The tailor's muscle, so called from the frequent use of it made by tailors in sitting à la Turque. The sartorius of the horse is denominated the adductor longus, in contradistinction to the adductor brevis answering to the gracilis.

[†] Birds instead of the pectineus have a thin muscle termed the accessory femoral flexor. It reaches to the knee and passes its tendon over the knee-joint, whence it retires to the back part of the leg, and runs, together with the flexor tendons of the toes, behind the heel. At the back of the leg its tendon divides; one slip or division goes to be inserted posteriorly into the metatarsus, the other slip joins the flexor perforatus of the first and last toe. Hence the flexion of the knee and heel produces mechanically a bent state of the toe, which may be seen in the dead bird; and it is by means of this structure that the bird is supported when roosting, without any muscular action. Blumenbach, *Manual*, p. 312.

[‡] Beautifully marked in the Torso.

descending from beneath Poupart's ligament, by the side of the sartorius, into the hollow of the femur.[*]

3. *Abduction* is performed by the *tensor vaginæ* already described; also by the *gluteus magnus* or maximus, and by the gluteus *medius*.[†] The *sartorius*, already described as a flexor, is another muscle employed in abduction.[‡]

4. *Adduction* is effected by means of the three adductors, alias the *triceps femoris* above-mentioned; also by the *pectineus* and *gracilis*, by the *psoas magnus*, and *iliacus internus*, already described as flexors; and further, by the *semitendinosus*, by the *semimembranosus*, and by the *long head* of the *biceps cruris*[§] already described as extensors.[‖]

5. *Rotation* is of two kinds; either for turning the toes *out*, which being in the direction of the fibula may be called fibular rotation; or for turning them *in*, which being in the direction of the tibia may be called tibial rotation. *Fibular rotation* is performed by the *gluteus magnus*,[¶] and partly by the *gluteus medius;* also by the *iliacus*[**] *internus* and *psoas magnus*, by the *triceps* or adductores, and in some degree by the *biceps cruris*, if the leg be extended. All these muscles have been described above.[††] *Tibial rotation* is made by the *tensor vaginæ* and by a portion of the *gluteus medius;* and if the leg be extended, these muscles are assisted by the *sartorius*, the *gracilis*, and the *semitendinosus*. Their description has been given in this article.[*]

(255.) The muscles to which belong the motions of the knee-joint in the human subject come now to be noticed. The movements of the tibia are limited to extension and flexion.[†]

Its *extensors*[‡] are, 1. The *rectus* cruris.[§] 2. The *vasti*,[‖] called internus and externus according to their situation on each side of the last muscle. 3. The *tensor vaginæ femoris*. (Art. 254.) 4. The *gluteus*[¶] *magnus*. (*Ibid.*)

The *flexors* of tibia are[**] the *gracilis*, *sartorius*, *semitendinosus*, *semimembranosus*, *biceps cruris*, *tensor vaginæ*, and *gluteus magnus*, already described. (Art. 254.) It will be observed of the two muscles last named, that they are employed both as flexors and extensors. They are so employed at certain stages of flexion or extension. Both muscles are tensors of the fascia called vagina femoris, which, since it extends

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[*] To these flexors Barclay adds the gluteus minor and obturator externus, both of which muscles have their movements effectually concealed; the former by the thick and fleshy fibres of the gluteus medius and gluteus magnus, the latter by various muscular strata in front, the uppermost of which are the psoas magnus, iliacus internus, and pectinalis.

[†] The gluteus *magnus* arises along the back part of the spine of the ilium; also from the outer part of the sacrum; also from the os coccygis; and lastly from the sacro-ischiatic ligaments. Its fibres are very large, and proceed obliquely downwards in a loose and folded mass to support with the greater ease the body when seated; and they terminate in a strong, flat tendon which passes over the trochanter major, and is inserted just below it into a rough surface at the upper and outer part of the linea aspera. The gluteus *medius* is in part covered by the magnus and arises from the remaining half, the anterior half, of the spine of the ilium; likewise from the dorsum, or outer surface of the ilium between the spine and the semicircular ridge. The fleshy fibres of this muscle contribute as they descend to mark the contour of the hip-joint. They converge into a broad tendon near the trochanter major, into the upper and outer part of which the muscle is inserted.

[‡] These abductors are further assisted by the gluteus minor, covered, as already observed, with the other glutei; likewise by the pyriformis, obturator internus, and by the gemini. These three last mentioned come from the inside of the pubis through the sacro-iliac and sacro-ischiatic foramina to be inserted into the fossa below the trochanter major. All three are covered and have their movements concealed by the gluteus magnus.

[§] The muscles situated on the back part of the thigh are three in number; the biceps flexor cruris, the semitendinosus, and the semimembranosus. The attention of the student must first be directed to the tendons of those muscles which form the hamstrings at the lower and back part of the femur, and at the back of the knee-joint. The outer hamstring is formed but of one muscle, the biceps flexor cruris; the inner hamstring is formed of two, the semitendinosus and the semimembranosus. Simpson, in *loc. cit.* p. 120.

[‖] To these add the *quadratus femoris*, a muscle behind the femur, and concealed effectually by the gluteus magnus. Add also another adductor muscle in front, *viz.* the obturator externus concealed by the psoas magnus, the iliacus internus, and the pectinalis.

[¶] The gluteus magnus or maximus in birds takes the form of a pyramid, whereas the pyriformis, properly so called, is absent.

[**] The iliacus in birds is represented by the gluteus minor, attached to the anterior edge of the ilium.

[††] The gluteus minor, the pyriformis, gemini, obturator internus, obturator externus, and quadratus femoris, may be added. (See Barclay, *On Muscular Motion*, p. 429.) But as their action is concealed, they are of little interest to the artist.

[*] The rotatory muscles of the human femur, when the femur is fixed, observes Dr. Barclay, are calculated to produce similar motions in the trunk.

[†] Its companion, the fibula, has no connection with the knee-joint, and follows implicitly every movement of the tibia, to which it is attached securely both by ligaments from its capsules at each extremity, and by the interosseous ligament between the extremities; also by muscles attached to it and to the tibia, *e.g.* the soleus, tibialis posticus, extensor longus digitorum, and flexor longus digitorum; and, lastly, by muscles that cross the interosseous space longitudinally, *viz.* the tibialis anticus, extensor proprius pollicis, and flexor longus pollicis. Barclay, in *loc. cit.*

[‡] The extensors, besides stretching out the leg, have the office, when the tibia is fixed, of bringing the pelvis and femur forwards over the leg. The *extensors* of the knee are much stronger in the human subject than in other mammalia, as their double effect of extending the leg on the femur, and of bringing the femur forwards on the leg, forms a very essential part in the human mode of progression. The *flexors* of the knee are, on the contrary, stronger in animals, and inserted so much lower down in the tibia (even in the simiæ) than in the human subject, that the support of the body in the hind legs must be very insecure; as the thigh and leg form an angle, instead of continuing in a straight line. *Ibid.*

[§] Sometimes called rectus tibiæ, or rectus femoris, which arises by two strong tendons from two portions of the ilium: one tendon from an interior process at the lower part of the spine of the ilium, the other from its outer surface, or dorsum, just above the acetabulum. The tendons soon unite in a thin flat muscle, widening towards the middle of the femur, whence it passes directly downwards to the patella, into the upper and fore part of which it is inserted, to be again inserted into the tubercle in front of the tibia by the ligamentum patellæ.

[‖] The *vastus internus* arises from a tendinous origin beneath the forepart of the trochanter minor, and from the *inner* and *lower* edge of the linea aspera. Its fleshy fibres proceed obliquely forwards down the femur, to be inserted partly into the tendon of the rectus, and partly into the *inner* edge of the patella. The *vastus externus* arises, broad, tendinous, and fleshy, from beneath the forepart of the trochanter major, and from the upper and outer side of the linea aspera. Its fibres proceed obliquely downwards and forwards, and compose the large fleshy mass on the outer side of the femur, but not continued so far down as those of the vastus internus. They are inserted partly into the tendon of the rectus, and partly into the *outer* edge of the patella.

[¶] To these add the crureus, or *cruralis*, which has its rise between the vasti, and has a common insertion with them into the tendon of the rectus. Hence the two vasti, the cruralis, and the rectus cruris, have been sometimes described under the term quadriceps. The cruralis is quite concealed under the other three. These muscles are well shown in the Hercules Farnese, Gladiator repugnans, and almost every antique statue. They are more prominent the more the leg is extended.

[**] To these add the *gemelli*, concealed by the gluteus magnus; and the *plantaris*, concealed by the external head of the gastrocnemius, and of which the only part discernible is the lower end of its inserting tendon united to the tendo Achillis. Also the *popliteus*, still more deeply seated than the last muscle.

over the knee, and on each side of the knee-joint to be attached to the heads of the tibia and fibula, will have those two parts, on each side of the centre of motion in the knee-joint, alternately stretched and relaxed during the process of bending or extending the leg. The fibres of the fascia that reach downward from these muscles outside the femur to the fibula, will help to bend the leg. The fibres, on the other hand, that extend obliquely across the femur to the tibia will (while they pass over the intervening inner condyle at the knee) extend the leg.

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(256.) The human foot is moved on its axis *upwards*, which is called flexion; *downwards*, which is called pointing the toes or extension; *inwards*, which may be called adduction, or turning *in* the toes; and *outwards*, which may be called abduction, or turning the toes *out*. The muscles, therefore, of the tarsus may, like those of the carpus, (Art. 245,) be divided into flexors, extensors, abductors, and adductors.

Its *flexors* are the *tibialis anticus*, the *extensor longus digitorum pedis*, and another muscle, sometimes wanting, which is properly a part of the extensor longus, called the *peroneus tertius*. Also the *extensor proprius pollicis pedis*, which, though the belly of the muscle is concealed between the tibialis and extensor longus, sends out its inserting tendon between theirs. The *extensors* of the tarsus are the *gemellus*,[*] alias gastrocnemius externus: the *soleus*, or gastrocnemius internus; both which blending inseparably their tendons, to be inserted together into the os calcis and to form the tendo Achillis, are sometimes called a *musculus triceps* (the gemellus has two origins) of the calf of the leg: the *plantaris*, sometimes wanting, of which the only part seen is the lower part of its tendon, near its insertion with the two preceding muscles posteriorly into the os calcis:[†] the *flexor longus pollicis*; and under it (concealed, but assisting to swell its dimension) the *flexor longus*[‡] *digitorum perforans*. To these add the *tibialis posticus*, of which the tendon only is visible, passing with that of the flexor digitorum behind the inner ankle through a groove in the tibia: lastly, the *peroneus longus*, and the *peroneus brevis*, whose tendons descend behind the outer ankle to the sole of the foot for insertion, the former into the metatarsal of the great toe, the latter into the metatarsal of the smallest toe.

The *ab*ductors of the tarsus are the *peroneus longus*, *peroneus brevis*, and *extensor longus digitorum*, together with its offspring already described, the *peroneus tertius*.[*] The *ad*ductors are the *tibialis posticus*, the *flexor longus digitorum*, and the *flexor longus pollicis*, already enumerated as extensors of the tarsus.[†] With respect to muscular action upon the remaining portions of the foot, *viz.* upon the metatarsus and the phalanges thereto appending, we despair of making ourselves intelligible by any outline in words; and we close this description with recommending, as we did for an acquaintance with the hand, (Art. 245,) a complete dissection of the tarsal as well as carpal extremities.

Outline of the *whole* figure to be studied, as well as outline of parts.

(257.) The chances, however, of drawing with incorrect outline a hand or foot, or any separate limb and feature, may be far less than the likelihood of failure in putting all the parts of a figure well together. Many can draw a single part with precision and with grace, who yet fail lamentably in arrangement of the whole. Perhaps this is easy of explanation. Such objects as in the life are oftenest presented to the artist's eye, he will be likely to paint best. We have, for this reason, been the more diffuse upon the relative position, origin, and insertion of such muscles as were familiar daily to a Grecian student among the Gymnasia of old in the Age of Pericles or Alexander; but which other times, and other customs, and, we may add, an unfriendly climate, must always render less accessible to the ablest modern Phidias or the most accomplished modern Apelles of the North.[‡] To sculptors the importance of having the whole figure well arranged is so apparent, that even in cases where folds of drapery cover almost

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[*] The extensors of the ancle-joint, and chiefly those which form the calf of the leg, are very small in mammalia, even in the genus simia. The peculiar mode of progression in the human subject accounts for their superior magnitude in Man. By elevating the os calcis, they raise the whole body in the act of progressiou; and by extending the leg on the foot, they counteract that tendency which the weight of the body has to bend the leg in standing. Lawrence's Blumenbach, in *loc cit.*

[†] The *plantaris* muscle, instead of terminating in the os calcis, expands into the plantar fasciæ in the simiæ; and in other quadrupeds it holds the place of the flexor brevis or perforatus digitorum pedis, passing over the os calcis in such a direction that its tendon would be compressed, and its action impeded, if the heel rested on the ground. Lawrence's Blumenbach, in *loc. cit.*

[‡] In birds the flexors of the leg and toes are remarkable. They answer to the flexores longi, and form three divisions, the first of which, again portioned into three, is a flexor communis perforatus. This muscle has two origins; one from the outer condyle of the femur continued into a perforated tendon to receive a tendon from the muscle that answers to our peroneus. The other origin which from the hinder surface of the femur gives out tendons for the index and digitus minimus pedis. Fibres from this flexor communis connect it with the accessory femoral flexor (see in Art. 254 note on the pectineus) already mentioned. By reasou of this connection, and the insertion of each flexor tendon into its appropriate unguinal phalanx, the inflection of the femur causes an inflection also of the toes enabling birds to clasp their perch during sleep. See Borelli, *de Motu Animalium*, pars 1ma. prop. 149 and prop. 150.

[*] The peroneus in the female foot does not appear. It is strongly marked in the Laocoon and Hercules Farnese. On the instep, between the extensor longus and the outer ankle is seen the extensor brevis, very prominent in the Laocoon and in the left foot of the Gladiator. The feet of the Hercules Farnese may here, as they may in every case, be consulted as perfect models.

[†] Observe that the flexors of one bone are often the extensors of the next adjoining boue. Thus the flexors of the femur have been numbered amongst the extensors of the tibia. (Art. 254.) So in the present instance, the flexors of the tarsus are found among the extensors of the toes, and *vice versâ*.

[‡] In the notes to a Poem entitled *Elements of Art*, published in 1809, from the pen of the present President of the Royal Academy, the reader will find, amidst much valuable information conveyed in a very lively manner, an observation, p. 142, that a modern Sculptor would not consider the practice of frequenting our pugilistic academies as "a very important accessory to his ordinary means of improvement; that to examine, to any purpose, the muscular forms seen there, he must take them to his study: and that the Romans, possessing similar opportunities with the Greeeks for studying the human form at games and public exercises, never approached the excellence of Grecian art." We are of opinion that the Gymnasia of the Greeks probably contained figures that showed intellectual as well as animal power, models of nobler expression, and personages more graceful, as well as loftier and more dignified in character and deportment, than our "pugilistic academies" can often boast: but we think that with such living Grecian forms before him an able artist would prefer catching the expression of unconscious and unrestrained subjects to confining them in his *studio:* and we agree with the author that the superior taste and civilization of the Greeks brought them to admire and imitate, what less-gifted Roman artists would overlook. The remark in an Essay of Hume, that "*nothing is more favourable to the rise of politeness and learning than a number of neighbouring and independent States, cemented together by commerce and policy*," may account for the non-advancement of the Arts in ancient Rome. The mistress of the world had no rivals. Her slaves were her teachers. She condescended to be taught. How could she be eminent in what she half despised? *Excudent alii*, &c.

the entire body, their practice is to complete a perfect model of the form beneath, before draping is attempted. It is upon the same principle that we would urge the pictorial student to consider muscles as a clothing of the bones; and so thoroughly, in the first place, to acquaint himself with the skeleton of any animal, as afterwards to clothe it with facility in all its appropriate integuments, and thus to show the whole figure well sustained throughout.[*]

Of superficial ligaments and fasciæ.

(258.) But this acquaintance, generally, with muscular configuration will be incomplete if it lead to forced and exaggerated outline. The muscles in the living figure, besides their covering of the skin, are so sheathed and rounded, and kept down by various fasciæ and ligaments, annular, capsular, and inter-muscular, that even in the most muscular living model they blend by degrees their boundaries, gliding softly and insensibly into each other, and have no markings that at any time, or under almost any circumstances, will be seen approaching to hardness. Of the superficial ligaments and fasciæ in the human subject it will therefore be necessary to make some mention. The *inguinal* ligament, called *Poupart's*, or the crural arch, along the spine of the ilium to the os pubis, has been noticed; (Art. 252;) it is a folding or doubling back of the tendon of the obliquus externus. The use of these ligaments generally is to bind down the tendons and prevent them from starting; and sometimes to give them, as by a pulley, a new direction. Each tendon for this purpose is enclosed in a smooth and well-lubricated tendinous channel, which is called a *capsular* ligament; also at the extreme joints of the limbs, both of the thorax and abdomen, are affixed tendinous bands, called *annular* ligaments, under which, through distinct rings or sheaths, pass the tendons of various muscles concerned in motions of the carpus and tarsus, and of their appending joints and phalanges. These bands furnish likewise points of attachment for the fasciæ that surround the arm and leg. At the wrist in the human subject, we need only here mention the *annular band*, or ligament, which at its broadest part is the breadth of a thumb, and which has the appellation of *anterior* or *posterior*, according to its aspect towards the palm, or towards the back of the hand; the former binds down and gives passage to the flexor tendons, the latter to the extensor tendons. Both ligaments are attached strongly to the articulations of the radius and ulna, and of the neighbouring bones of the carpus, which they assist in connecting. Again, at the ankle-joint observe the *deltoid* ligament descending from the inferior border of the *inner* ankle to the inner part of the astragulus and os calcis, to form a band for the tendons of the flexor longus digitorum, and of the tibialis posticus: also from beneath the *outer* ankle to the outer side of the os calcis a second band for the tendons of the peronii; and a third in front above the instep, situated between the ankles, and joining the former two, gives passage to the tendons of the proprius extensor pollicis pedis, and (through four distinct rings or sheaths) to the four tendons of the extensor longus digitorum.

(259.) Among the *fasciæ*, or aponeuroses,[*] we may begin with noticing, 1. That of the occipito-frontalis muscle spread, tendinous, over the crown of the head. 2. That of the *temporalis* has been already named. (Art. 232.) 3. The *platysma myoides* may be here included, originating by extremely delicate fibres from the cellular membranous covering of the pectoralis and deltoides, and inserted into the skin and muscles of the lower jaw and cheek. Acting as a muscle, it draws downwards the skin of the cheek, and when the mouth is shut, draws the integuments of the neck upwards. It is introduced in this place from its inseparable connection with a thin fascia interwoven with its fibres, termed the *cervical* fascia, which binds down and invests the front and sides of the neck. Through this

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[*] Such a view of the subject seems yet more necessary to Painting than to Sculpture, since the sculptor is not troubled, except occasionally, in relievo, by rules of linear perspective. But Painters are confined to a flat surface, and to only one aspect of the form which that surface is to represent. Painters, therefore, must be careful to keep the painted form within perspective rules, and must be careful in proportion to their greater difficulties; for the Painter may be often overwhelmed with foreshortenings in cases for which a statuary has the advantage of actual measurement, and which, to the latter artist, may be the simplest cases possible. A method may here be mentioned, which we know has been successfully pursued. Let the human skeleton, or that of any animal, *drawn in some natural position*, be painted in oil upon a panel of sufficient dimensions to show distinctly the features, joints, and general character. When the Painting is sufficiently dry, rub the surface with a little finely powdered pumice-stone till it will admit a coat of water colour, prepared of any earth or ochre mixed with white chalk, to suit the tint of the intended subject: let the student then take his hair pencil, and with a full brush of colour lay *on* the various strata of the muscles; only in the inverse order to that adopted by an anatomist in dissecting them or taking them *off*: for the dissector, beginning, of necessity, with the outside, calls that outside coat the first layer of muscles; and so proceeds through the second and third layers till he reaches the fourth, which lies nearest to the bones. *Our* practitioner, on the contrary, may begin with the fourth, or with the third, of which he need not be very minutely careful, since those muscles are seldom subjects for the Painter; but to the second and to the first layer, since these give form to and partly constitute the superficial boundaries, he must pay diligent attention. It was with this view that we have endeavoured in the preceding columns to select, and to describe for him, the most remarkable of the superficial muscles, particularly in the human subject. He will scarcely find an easier mode of fixing in his memory, and of familiarizing to his eye, the shapes, use, origin, insertion, and situation of these all-important instruments of animal motion. A peculiar advantage of this method is, that the whole, or any part of the water colour may be at any time effaced with a wet sponge, when the painting of the bones will again reappear, and may again be coated with larger or with smaller muscles at pleasure. For the connection of the bones and muscles, see a short but complete Manual, 12mo. by J.F. South, 1828.

If further practice be desired in this way, let the student prepare dark tints, variously tempered with the lighter material, and proceed to shade every muscle according to its natural prominency and the degree of light introduced over each part of the figure. For this purpose, let him first draw, or paint in a skeleton form, any fine statue or group; and after carefully marking the position of the several joints and bony protuberances, cover the whole with muscles, as seen in the marble or cast before him. Oil paintings of skeletons from the antique, to be afterwards worked upon with water colour in the manner above suggested, might furnish useful practice for such as commence the Art. It will moreover be evident, that by varying to any required extent the posture of the skeleton animal, the foregoing method may be rendered universally useful in the drawing-school, for acquiring, in a shorter space of time than perhaps is usual, a more than usual acquaintance with Myology.

A very complete Work in folio was published at Paris in 1812, by Jean-Galbert Salvage, *Docteur en Médecin*, entitled *Anatomie du Gladiateur combatant;* the plates to which effectually illustrate the method of practice which we have recommended above. See also Tuson's *Myology Illustrated*, fol. 1825. On the same subject there is a Work translated from the German of Lavater, published in 1824 by Ackermann, expressly for artists.

[*] In various parts of the body the tendons may be seen expanding themselves into a broad flat membrane, and forming what is called an aponeurosis or fascia. The use of these fasciæ is to cover the muscles, and give attachment to many of their fibres: they also dip down between the muscles, and, forming partitions, adhere to the ridges of the bones, and thus prevent the muscles from starting or swelling too much when in violent action.

fascia and platysma, and in the direction of the sterno-hyoides muscle, is seen occasionally a convexity in the throat called the pomum Adami, generally larger in the male than female subject. 4. The *brachial* aponeurosis arises from the tendons of the latissimus dorsi and pectoralis muscles on each side of the arm-pit; also from the tendinous insertion of the deltoides; also at the back part of the arm, from the spine of the scapula (Art. 233) and the fascia of the infraspinatus. From these origins it expands, like a sleeve, downwards over the whole arm, enveloping the muscles, and covering the brachial vessels and nerves, where they descend along the inside of the limb. It becomes fixed below into the condyles of the humerus, and to the several neighbouring ligaments between the muscles, and then proceeds to form, 5. The *fascia of the forearm*, a strong and thick covering, but more especially so at the back of the limb. The tendinous investment, which in the upper joint or humerus was thin and weak, now becomes dense and powerful; it is attached to the condyles, and adheres firmly to the olecranon, or upward projection of the ulna. Behind the arm it is strengthened by fibres from the triceps extensor, and in front it appears a continuation, as has been said, of the brachial aponeurosis sent off from the biceps flexor cubiti. It descends over the forearm, binding down the muscles, and sending processes between them, and is continued below into the annular ligaments (Art. 258) of the wrist. From this tendinous bracelet at the wrist arises, 6. The *fascia palmaris*, which expanding over all the palm of the hand, is fixed to the roots of the fingers, splitting to transmit their tendons. It is strong and thick, and conceals the muscles of the hand, while it gives them powerful support. 7. In the region of the abdomen we have the fibres of the *obliquus externus* descendens terminating downwards in a broad thin aponeurosis assisting to support the viscera. 8. The *fascia lata* is a very strong, smooth, and tendinous expansion on the outer part of the femur. On the anterior and inner part it is very thin and of a cellular texture. It surrounds the femur, covers all the muscles, and is pierced by many small foramina for vessels and nerves. The fascia lata, as its name imports, is most extensively connected with bones, tendons, and ligaments in the abdominal region.[*] It receives a number of fibres from the muscle peculiar to it, called the tensor vaginæ femoris, and also from the tendon of the gluteus magnus. Below it adheres to the common tendon of the rectus and vasti muscles, and to an aponeurotic expansion over the knee-joint; and it is continued over the knee to be attached to the heads of the tibia and fibula, after which it forms, 9. The *fascia of the leg*; which is not only a prolongation of the fascia lata, but receives fibres from the tendons of the sartorius, gracilis, and semimembranosus, as well as from the tendinous expansions of the rectus and vasti femoris.[*] 10. Lastly, the *fascia plantaris* requires our notice, bearing some analogy to the fascia palmaris already described.[†]

Of Outline.

(260.) No apology can be necessary to the artistic inquirer, for our having given as minute attention as our limits will permit to the foregoing particulars. If intimate acquaintance with the superficial muscles be absolutely indispensable, there must likewise be still further occasion for a perfect knowledge of those parts which appear above the muscles. Not only the fasciæ we have been enumerating are essential characteristics of the external fabric, but a multitude of veins also which protrude themselves outside the surface of the fasciæ, and are seen through the skin.[‡] We have already alluded to certain veins and arteries in the region of the head. (Art. 232.) In the arm we have yet to mention several cutaneous veins which ramify upon its fascia. The principal are the vena basilica, the vena cephalica, and the vena mediana major. 1. The *basilic* vein arises from a small vein, called the salvatella, outside of the little finger, then runs upwards inside of the forearm in two branches, which receive in their course a number of smaller ones; and which, from their proximity to the ulna, are called the anterior and posterior *ulnar veins*, the posterior being the largest. The basilic vein next passes over the fold of the arm, and is here joined by a vein, to be again noticed, called the median-basilic; it then becomes deeply seated, and disappears a little above the elbow-joint.[§] 2. The *cephalic* vein commences also at the back of the hand by a plexus

Of cutaneous veins.

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[*] In the upper and fore part of the femur it arises anteriorly from the spine of the ilium, from Poupart's ligament, and from the os pubis: on the inside of the femur it springs from the descending ramus of the os pubis, and from the ascending ramus and tuberosity of the ischium: behind the femur, and on the inside, it arises from the surface of the sacrum and coccyx, and is continuous with the cellular covering of the gluteus magnus, which muscle, however, is not bound by any distinct fascia or aponeurosis: it is at the anterior edge, and on the lower fibres of the gluteus magnus, that the commencement behind of the fascia lata appears. Thus extensive in its origin, the fascia passes down over the whole thigh, covering and enclosing the muscular mass, and sending septa, or processes, inwards through the femur, which form cellular sheaths for several of the muscles. By one of these processes, or laminæ, it is firmly fixed to the outer edge of the linea aspera. But the main body of the fascia does not give origin to muscular fibres, and is a complete *vagina* unattached.

[*] It adheres firmly to the heads of the tibia and fibula; and, in its passage downwards, adheres also to the inner edge of the front of the tibia, uniting itself inseparably with the periosteum: it entirely invests the leg, but is thickest in front; behind and at the lower part of the leg it is much thinner. It again becomes very strong where it passes over the ankle-joint, in consequence of its adhesions about the outer and inner malleolus: here it again joins the annular ligament already mentioned, (Art. 258,) which is described in the *London Dissector*, (a work to which we are indebted for the greater part of our information,) as being in fact only a thicker and stronger portion of the fascia of the leg. Below, and in front, the fascia of the leg terminates by a thin tendinous expansion that covers the instep; behind, it is lost insensibly on the heel; on the outer side it is connected with the sheath of the peronei muscles, and on the inside it is affixed to the internal annular ligament.

[†] It is a very strong tendinous expansion, which arises from the projecting extremity of the os calcis, and passes forward over the sole of the foot to cover and protect the muscles; it is triangular. At its origin from the heel it is thick but narrow; afterwards it becomes broader and thinner as it proceeds under the foot, and is fixed to the head of each of the metatarsal bones by a process which, splitting, leaves room for the tendinous vessels and nerves to pass.

[‡] Our limits will not permit such a comparative view as would include a description of these veins in quadrupeds, but the student will find, in pursuing the inquiry, that the parts of quadrupeds analogous to those in the human subject have similar fasciæ and veins, which, running over them, show, in like manner, their branches immediately under the skin; they are more or less visible according to circumstances. In general those vessels appear most distended and fullest in any member which lie lowest, and whose fluid contents, in finding their level, must accumulate by a force of gravity corresponding to the posture of the limb. For this reason, in quadrupeds, the pectoral and thoracic veins are conspicuous. Also any incidental stoppage of the circulation will cause a swollen appearance of the veins in that portion of the limb where an accumulation of blood is induced.

[§] For examples of the basilic vein, see the Hercules Farnese, the Sleeping Faun, and the left arm of the Hæmon. The left hand of the Laocoon admirably exhibits the disposition of the veins; and must divide, with the foot of the Hercules, the attention of every student in outline.

of veins, uniting into one trunk, named vena cephalica pollicis, situated between the thumb and metacarpal bone of the forefinger. Passing along the radial side of the arm it takes the name of the superficial *radial vein*, and receives cutaneous branches from both surfaces of the forearm. Ascending over the bend of the arm, near the outer condyle, it is joined at this point by the median-cephalic not yet noticed, and continues its course upwards near the outer border of the biceps flexor cubiti, and afterwards between the deltoides and pectoralis major, till it dips inwards under the armpit to enter the axillary vein. 3. The *median* vein is a trunk between the two former, supplied by several veins that run along the middle of the front, or flat side of the forearm, on a line with the palm of the hand. At the fold of the arm the mediana major divides into the two branches that have been mentioned; one of them, *mediana basilica*, being a junction obliquely with the basilic vein; the other, the *mediana cephalica*, with the cephalic. A third retiring branch, and therefore unimportant to the painter, sinks inwards to join the deeply-seated veins.

(261.) In the femoral extremity, the student will remark the vena saphena major and the vena saphena minor. 1. The *saphena major*,[*] commencing from veins on the inner side and forepart of the foot, is seen crossing over the inner ankle; then running upwards upon the inside of the tibia it ascends behind the inner condyle: it is next seen climbing up the inside of the knee and of the femur, under the name of the saphena interna. At its first appearance it is very distinct and superficial; but as it ascends the femur it becomes enveloped by the fibres of the fascia, and at length, about an inch and a half below Poupart's ligament, sinks beneath the falciform process of the fascia lata to join the femoral vein in the groin. In its course it is joined by several cutaneous veins from the thigh. 2. The *saphena minor*, or externa, is situated between the muscles of the calf and the fascia in front of the leg. It begins by cutaneous branches of many small veins on the outer ankle and outer side of the foot, and is seen ascending from the outer ankle over the tendo Achillis, and along the middle of the gastrocnemius muscle to join the popliteal vein. At first it is very visible in its course immediately under the skin, but in the upper part of the leg this vein sinks gradually between the laminæ of the fascia to enter the poples or hollow of the ham.

Outline of Landscape.

(262.) On the subject of Landscape we have here to perform our promise of giving some observations. The varieties of outline in Landscape result chiefly from changes of the season and of the weather, much after the same manner as the outlines of interior or in-door grouping result from the agency of human contrivance, and from gestures voluntary or involuntary.

Landscape has commonly been divided into foreground, off-scape, or middle ground, and distance. Of these three the middle ground, as it generally comprises the greatest number of distinguishable objects, is capable perhaps of the most interesting variety. To begin, however, with

1. The distance. Very remote objects are only and dimly visible in large masses. They consist chiefly of clouds and mountains, with occasionally the horizon formed by the surface of a lake, or of the sea, or of some wide flat moor-land. Lines representing the most distant clouds or waves will become, the more nearly they approach the horizontal line, more and more parallel to it. Objects at sea, as ships, &c., (if distant more than five miles from a spectator standing on the shore,) must be represented with their lower portions more or less beneath this intervening horizontal line of water. But observe that, in a hazy atmosphere, this horizontal line is higher than at other times, and at some little distance above the ordinary perspective horizon, (Art. 11,) a distance greater in proportion to the degree of haziness. The height of the horizontal line H L (plate i. fig. 1.) above *p o*, *i k*, or *a d*, the base or bottom of a picture, also depends upon the nature of the subjects to be introduced. If much foreground or middle ground be required, the eye of the spectator must be placed higher to command the view. The horizon of course rises with him. Some great authorities in landscape, Poussin, for example, have chosen to place the horizon about one-third from the top of the picture. This arrangement is favourable for the sublime effects of mountain scenery, and unfolds a kind of bird's eye view considerably below the level of the spectator's feet, or of the ground plane. Other great artists, as Claude of Lorraine, have placed their horizontal line about one-third from the bottom of their canvass, thus obtaining a larger portion of sky, and consequently of aerial light.

2. The foreground. The nearest objects have their outlines most distinctly marked, especially such as lie near C, (plate i. fig. 1,) the centre of the picture. We before observed (Art. 15) respecting the circle of vision, of which F R (plate ii. fig. 5) is diameter, as well as respecting the circle of distinct vision, of which V X is diameter, that within any given intervals, as V F, or X R, between the two circles, the objects become clear as they approach to C. Upon the same principle also, the distinctness of objects *within* the circle of distinct vision increases as they approach the same point C. Not only in the outline of figures or buildings, but in the foliage of trees, shrubs, or plants, undulations of water, &c., the most articulate and careful markings may be here required. Among foliage, close to the plane of the picture, an outline, even of leaves and flowers, may be occasionally given with good effect, provided they be kept to their natural size, determinable by the proportions of the principal distance. (Art. 39. *et seq.*) It is recommended for drawing readily the outlines of foliage, that the student previously apply himself to learn the touches of some able master. Besides many Works of modern Art for this purpose, good engravings from Titian, Caracchi, and Rubens, may supply examples. From Claude there is a very characteristic set of engravings by Earlom, the *Liber veritatis*. No sooner, however, is competent execution obtained in this branch of drawing, than the artist must resort to the book of Nature for the forms and characters of his trees. Not only must he select for himself such as present picturesque objects for study, but he must remark, with something of the eye of a naturalist, every peculiarity in the shape of bark or foliage, as well the usual height from the ground at which the main branches of each are seen to fork off from the trunk and at what angle.[*] Similar observations apply to the delineation of water, and the

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[*] The saphena major runs differently in different individuals, but generally takes the course given to it in the legs of the Hercules Farnese and in the Sleeping Faun.

[*] The edition of the *Trattato della Pittura*, by Manzi, contains many remarkable observations from Da Vinci, on foliage and on Landscape generally, not before published.

more or less distinct outline of its waves. By the influence of wind it takes the direction of the waving line *i o* D, *i o* C, or *i o* B. (Plate xi. fig. 3.) The effect also of wind upon clouds is infinitely diversified. As a general rule, let the roundest and fullest portion of a cloud be that which, like the bosom of a sail, is furthest from the wind, and let its scattered portions be represented to windward. The same outline applies to the representation of smoke. Very high clouds assume a level form.

3. Respecting the middle-ground, which, as its name imports, is between the near-ground and the distance, the outlines are less articulated. They become more indistinct, more rounded, and more grouped in masses, in proportion as they recede from the eye. Large trees, which upon a closer view would show distinct branches, must now be massed into round or spheroidal forms. The surface of the roughest water, as it nears the horizon, approaches to a smooth line. In the middle-ground the same result of a foggy atmosphere may be shown by the same kind of enlargement in the size of objects, as was observed above respecting the effect of haze upon the horizon and objects in the distance. Observe also, that the sky over the middle-ground, like that over the distance and over the front or fore-ground of the picture, partakes in its outlines of the same general appearances as belong to the several districts immediately underneath it. Near the spectator the clouds are to be distinctly and carefully marked, though without hardness. Insensibly their articulations become less and less discernible, until, in the horizon, they may be said to melt into space.

(263.) Next to configuration we proposed to treat of *expression.** That certain lines, curved lines, straight lines, or combinations of either, have the power of conveying through the eye impressions peculiar to each form, has long been a received theory. Like all theories, it may be absurdly overstrained. But nothing seems more probable than that out of the general appearances of nature to the sight and to the imagination, some general deductions have been tacitly and yet universally made by mankind, constituting the parent stock upon which systems of taste have been engrafted.*

(264.) A perfectly straight line, however placed, whether alone or with other straight lines, in any direction, gives no idea of life or of voluntary motion.† Drawn horizontally (see note to Art. 263) it implies flatness, and quiescence, and rest. But it is the flatness and quiescence of no living thing.‡ It is the rest of death, or rather the fixedness of an object that neither has had, nor can be expected to have life. It marks, to

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* It might, perhaps, be doubted whether expression comes properly under the head of outline. But experience decides otherwise. For let the merest novice in Art attempt the outline of any figure animate or inanimate. The first spectator to whom he submits his work, will immediately remark upon its merit as a resemblance intended to express some quality in the object represented. If the outline, for example, be of a human subject, some character is annexed to it. It is pronounced to be either young or old, handsome or deformed, pleasing or disagreeable, or is considered as expressing some particular sentiment of the mind, or some peculiar habit of the individual. If designed for a likeness, the critic instantly examines its proportions. The nose is too long or too broad; the eye too large, or too diminutive, or too prominent; the mouth nearer to the nostrils or to the chin; the lips wider, or thinner, or narrower, than in the life. Or, if the general likeness be admitted, then it is or is not flattering. The face is too cheerful or too thoughtful, too youthful, too handsome, or too otherwise. Or let the drawing be of a horse or cow, or any animal, its make, its breed, or other peculiarities will be observed upon, and its proportions inquired into, together with the aptitude of the limbs assigned by the draughtsman for its support, or for *expressing* any motion that may be represented. Even in viewing representations of inanimate objects throughout the world of Art or of Nature, the mind of the spectator passes judgment upon the *sort* of building, the *sort* of carriage, the *sort* of tree, &c., and the critic exclaims at once against the shape of such a mountain or of such a river, or of such a cloud that it is *unnatural.* All this criticism, be it observed, is called continually into exercise by mere outline; and whether the judgment passed be just or unjust, a proof is given that expression of some kind or of some degree belongs to this division of our inquiry.

* There appears no absurdity in maintaining, that as varieties of motion or position give to natural objects peculiar changes of conformation or outline, the lines which represent those changes should be conceived to have some necessary connection with the original movement or position so represented. Thus, whenever, as commonly it happens, during any violent action or agitation in nature, the objects convulsed and agitated take abrupt, irregular, and jagged forms; an association thereupon becomes established in the fancy of the spectator between such outlines and the scene of terror, or of confusion and wildness which they call up to his memory. The distorted features and startling gesture of a man phrenzied by passion; or, in a storm at sea, the tremendous declivity of waters alternately gulf and mountain, that rise like "Alps o'er Alps" in endless yawning curves of sharp-pointed waves; the zig-zag lightning; the confused intersection of innumerable lines among shivered masts and torn rigging; are likely to imprint themselves indelibly on the "mind's eye." Such lines, therefore, would come to be considered indicative of sudden motion or emotion, and classed in the alphabet of taste among appropriate characters for the terrific or the sublime. Let us next picture the opposite to such a scene: perfect calmness and placidity; a sky without a cloud; a horizontal line unbroken by either mountain or wave; no sign of movement any where. This straight, undeviating, horizontal line might very naturally be adopted for expressing rest or fixedness. And another straight line perpendicular to this, might, on similar principles, express firmness or security, namely, the general state of bodies resting perpendicularly upon horizontal bases. The impression, too, respecting security would be stronger as the base is extended. If, indeed, the straight line be seen inclined to the horizon, we, of necessity, regard the object as falling, or for a time only kept from falling, like the tottering wall of a dilapidated building. Thus, the straight lines at A and B (plate iv. fig. 2) inclined to the horizon C D indicate a propensity to fall: A toward C and B toward D. But let the lines A and B be joined at E, (fig. 3,) the idea of insecurity and dilapidation ceases, and the figure A E B supported on the base A B is endued with pyramidal stability.

† A straight line divided regularly denotes method and design, but is often too precise and formal for pictorial effect. Divided irregularly it denotes confusion; but divided so as that the parts shall bear a certain proportion to each other, it becomes agreeable: *e. g.* in a perspective of the wings and centre of the building, and in the forms of crystals, wherein the arrangement may be so wonderfully varied as to be pronounced beautiful. In living subjects a straight line combined with curves, indicates direct motion or instantaneous impulse by the extension of a limb: *e. g.* that of the index finger used in pointing, or the sudden spread of all the fingers in an action of surprise, apprehension, or terror.

‡ It is observable that in a state of perfect quiescence or sleep, the limbs of a living subject are considerably inflected. Animals most commonly will be seen sleeping or lying at rest with their legs gathered up. Sir Charles Bell remarks, in his *Essays on Expression*, (p. 184.) that there is a drawing together of the body and limbs in deep sleep, unless where mere gravitation stretches the legs, or where the posture of the sleeper prevents it. In death, he adds, the body is heavier, that is, the position of the limbs is more under the influence of mere gravitation. Rubens has given some very rude sketches to show that the elemental form of death is the straight line. The first effect of death is relaxation, but the second effect is stiffness and rigidity. But independently of this straightness and rigidity, there is a distinction between sleep and death, in posture as well as in colour and feature. In sleep there is a certain regard to convenience, and a uniform and gentle curve or flexure of the limbs; while in death there is entire reference, in the position, to the ground on which the body is laid. (See the first note to Art. 279.) The character is most distinctly marked by the position of the head and neck,

——————— *lentaque colla*
Et captum letho posuit caput arma relinquens.

the eye, a distinction between the barren impenetrable solid and the luxuriant vegetable; between the unyielding edges of a rock and the soft tendrils of the vine curling and bending over it. In order to be a sign of animated nature, a line must change its rectilinear state, and become a curve or succession of curves. The line designated by our inimitable Hogarth the "line of beauty," comes under this description. It contains no violent curve. It has no approaches to an angle, no breaks nor abruptnesses. But it expresses either easy, graceful, dignified motion, or the repose of conscious superiority.* To give it proper value, it should appear in the neighbourhood both of right lines and of circular undulations, or of lines more curved than itself. Placed near a right line, its gentle windings show more energy. Placed near lines of greater curvature than its own it becomes comparatively subdued. For this purpose,† the curved lines (in landscape and in architecture) which occasionally present themselves, may be so varied by Perspective, as to cooperate essentially towards graceful expression. The folds also of drapery may promote the same end,* and might be quoted to exemplify the

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[*] Hogarth, in his *Analysis of Beauty*, p. 37. concludes all visible objects whatsoever to be bounded and circumscribed by *the straight line* and *the circular line* with their different combinations and *variations*. He observes, that straight lines vary only in length, and therefore are least ornamental; that curves, as they can be varied in their degrees of curvature, as well as in their lengths, begin to be ornamental; that straight and curved lines joined vary more than curves alone, and become somewhat more ornamental; but that the waving line, or line of beauty, varying still more, being composed of two curves contrasted, becomes graceful, and leads the eye in a pleasing manner along the "continuity of its variety." He afterwards (p. 60.) exemplifies this, and supposes a small wire that has lost its spring, and so will retain every shape it is twisted into, to be held fast to the outside of the hip of an anatomical figure, and thence made to descend the other side of the femur obliquely over the calf of the leg down to the outer ankle, all the while pressed so closely as to touch and conform itself to the shape of every muscle it passes over. If this wire be then taken off and examined, it will be found that the uninterrupted flowing curve, which a living model might have given to it, is broken into many distinct and separate curves by the sharp indentures it has received at those points where it has been closely pressed in between the muscles. He next directs a similar wire to be in the same manner twisted round the same limb of a living subject, or of a fine statue, and observes, that no sharp indentations, or breaks, will attend this second experiment; that the changes in the shape of the wire are gradual and imperceptible, and that "the eye admires it, and glides easily along the varied wavings of its sweep." Mengs, the contemporary of Hogarth, and who was about the age of twenty-five when the latter, in his fifty-sixth year, published the *Analysis of Beauty*, has the same ideas conveyed thirty years afterwards in the more polished language of his posthumous editor, the Chevalier d'Azara. We quote the Italian edition of 1783, vol. ii. p. 244. *Le linee rette debbonsi convertire in ondeggiate: lo che non pregiudicherà alla forma principale, osservando che le porzioni di circolo tocchino in varj punti, distanze, ed elevazioni la retta, e non formino niun angolo, ma vadano continuamente alternando le* concavità *e le* convessità. *Una linea così fatta è la più a proposito per dar grazia ed eleganza al contorno.* Our own Flaxman (*Lectures*, p. 177.) gives one simple instance of opposition, and another of harmony, in lines. "Two equal curves, set with either their convex or concave faces to each other, produce opposition; but unite two curves of different size and segment, they will produce that harmonious line termed graceful in the human figure." It is to be remarked of Michael Angelo's drawing, that it is bold. His outlines are rounder than the lines of Raffaelle, which have more repose and grace. Rubens, says Mengs, (p. 296 of the volume just quoted,) by making his convex lines too round, produced vulgar and heavy forms. Corregio obtained the perfection of elegance and lightness by a proper union of convex with concave lines; while Caracci, his imitator, departed from this happy equilibrium by too great convexity.

[†] An acquaintance with Architecture is essential to the Painter. "Some of the best Painters of the English School," observes a judicious modern critic, himself one of its living ornaments, "discover a deficiency of knowledge in architecture, the more inexcusable because so easily supplied: but the prevalence of this defect is perhaps most glaringly displayed in our portraits. The pillar and the curtain shift from side to side of the picture in clumsy combination, through all the varieties of sameness, exposing at once our deficiency of other materials and our abuse of these. The works of the old masters show how assiduously they courted the assistance of this ally, and what they thought useful, we are not in a situation to disregard. Poussin and Paul Veronese were prodigal of their architectural knowledge, and often communicated an air of magnificence to their compositions, which raised the character of the subject by the dignity of the scene." *Elements of Art*, p. 90. note.

[*] Among the valuable Lectures of Flaxman is one on the subject of drapery, which the student of Outline will do well to study diligently. The Lecturer divides the mechanical structure of draperies as caused by the simple lines of their folds, into 1st. *The perpendicular fold*, hanging from one point. (Plate iii. fig. 18.) 2dly. *The succession of diagonal folds*, falling from each other hanging from two points, and which may be varied to a beautiful infinity; (plate iii. fig. 19.) for example, falling from the two points of the shoulders in the hollow of the back; or from the two shoulders over the projection of the breast and abdomen; falling from one shoulder, and from the lower arm making the principal folds below the elbow. And again, each of these may follow every change of position and motion. 3dly. *The cascade of diagonal* forms produced by the edges when diagonally folded towards the extremity. (See fig. 18, 19.) These three classes contain the principles of all folds, however produced, in all garments and draperies. Drapery, like all other bodies, is subject to the laws of gravity and motion by which it is affected according to its lightness or weight, strength or weakness, the repose or action of the wearer, and the force of wind; it is affected by these causes, simply or complexly, as it may be acted on by their separate or united force. The most simple forms of drapery are produced by the weight of the cloth itself, as it hangs from the most projecting points of the figure, and resembles a pointed arch reversed. A succession of such folds, broken into various lengths, and opposed in their diagonal forms, are among the boldest and most beautiful effects of drapery. The varieties produced from suspension are multiplied, and altered according to the portion of the figure they pass over, and according to the fineness or thickness of the cloth. If a garment, such as the Roman tunic, (in form nearly resembling a waggoner's frock,) be confined round the waist by a girdle, the folds will be of the inverted arch kind arising from the shoulders; and below the girdle they will fall in perpendicular masses of folds over the lower limbs, when the figure is not in action, or preparing for action. The sleeves, if full, will begin with folds falling from the shoulders before and behind, but these folds will be widened and changed into cross folds at the bend of the arm, and continue crossing the lower arm, more or less diagonally to its termination at the wrist. The folds become more or less diagonally spiral *from* the body if the arm is turned outward, and *toward* the body if the arm is turned inward. The folds on the back of the lower arm owe the upper portion of their direction to union with, or separation from, a projecting knobbed fold at the elbow. The same principles of folding on the arms will govern all coverings, from the fullest and most redundant, to the straightest and most exactly fitted to the limb. Respecting the effect of motion upon drapery, as soon as a limb is moved from a perpendicular into a horizontal direction, the drapery hanging on it changes the forms of its folds. The perpendicular folds bend by their weight into a curve, from the impulse of motion, or change from a perpendicular to the inverted arch: the strongest portion of the fold depending from the stronger of the two supporters, whether it be that part of the person which is in rest or that in motion. This is more particularly seen in the cloak or loose upper garment, but the principle is evident in all drapery worn by the human figure. For example, the lower portion of a tunic falls in perpendicular folds from the greatest projection in front of the figure, and becomes curved, clinging in the lower extremities to the unmoved leg, until that limb is set forward, when the same change is produced on the other side. This effect is still more evident in running, when the curved folds at last become horizontal, at right angles with the limbs. Motion of the figure affects the whole mass of drapery about the body; the folds are most interrupted and broken on the side moved in shortest space, as the curves are most lengthened on the side moved in a greater extent, and they are twisted most diagonally where there is the greatest power of motion. Upon the legs the folds change from downright to long curves, in walking or running alternately as one leg or the other is set forward. The greater quantity of folds naturally falls in the hollow spaces, and in quick motion the heavier portion of folds are left behind the figure by their own weight, in a

difference between an Outline, of abrupt motion, and of perfect rest. The flutter of a disordered dress placed upon the figure of Milton's personification of *Melancholy*, described as a

——— pensive Nun, devout and pure,
Sober, steadfast, and demure,

would effectually destroy the charm of her pensiveness. The poet, addressing this fair creation of his fancy, desires her to

——— keep her wonted state
With even step and musing gait,
And looks commercing with the skies,
Her rapt soul sitting in her eyes.

And he has accordingly clothed her as becomes her peaceful, solemn, contemplative character,

——— in robe of purest grain
Flowing with majestic train,
And sable stole of Cyprus lawn
Over her decent shoulders drawn.

It is impossible to conceive the outlines of this robe of "divinest melancholy" as having any abruptnesses, or indeed as having many varieties of undulation. The stole, which the Lexicon of Facciolati, under the word *stola*, defines to be a matronly garment, *rugis plicisque abundans*, would doubtless have numerous folds descending on every side in long perpendicular lines, and bounded below by curves, of which the smoothness and regularity would, in our present example, indicate the almost motionless state of the wearer, "forgetting herself to marble."

(265.) It has been made a question, whether beauty of form and fine proportions* are essential to expression. To this it may be replied, that they are very excellent adjuncts when introduced with propriety, though many

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diagonal curve, from the point on which they are supported. Lastly, with regard to the motion of drapery independent of the wearer, and caused by wind, of which the effects are more seen in those parts of the garment extended beyond the outline of the figure, observe the effects of wind on flexible and fluent bodies in general. The wind blowing on water, by pressure on a small portion of the fluid nearest, forces it into a wave, from resistance of a body of water not affected by the wind, on the other side of it: or else the wind, blowing obliquely on water, is resisted by the mass beneath until the surface is raised into a wave, which, bending over the wave before it, falls by the laws of gravitation into the surface again. There is a propensity to the same forms and successions in smoke, in clouds of the sky, and dust of the ground driven before the wind, and from the same causes. The pendant, or streamer, hanging from the top of a mast, is driven by the wind in the same direction, and may be represented by the same section as a succession of waves on the water. (Plate xi. fig. 3.) Progressive movement of the figure changes the perpendicular of falling folds into undulations. This is more evident as the motion becomes quicker. But the wind undulates all draperies; when moderate the undulation is diagonal, and when violent, it is horizontal. For further acquaintance with this subject consult Da Vinci, *Trattato della Pittura,* cap. 358—364; or in the edition of Manzi, p. 264—271.

* The following proportions are given by Watelet:—*Voici donc, d'après de Piles, quelques détails sur les proportions qui en donneront une idée à ceux qui ne les connoissent pas et qui ont peu de notions sur cet objet. Quant aux artistes s'ils ne s'en contentent pas, cette disposition tournera sans doute, au profit de leur instruction, parcequ'alors ils prendront euxmêmes, le soin de mesurer les antiques dont les copies moulées sont assez justes, et de les comparer avec la nature bien choisie.*

Les anciens ont pour l'ordinaire donné huit têtes à leur figures, quoique quelqu'unes n'en ayent que sept; mais l'on divise ordinairement la figure en dix faces, savoir depuis le sommet de la tête jusqu'à la plante des pieds de la manière qui suit.

La partie qui s'étend depuis le sommet de la tête jusqu'au front est la troisième partie de la face.

La face commence à la naissance des cheveux qui sont sur le front et finit au bas du menton.

La face se divise en trois parties égales.

1. *La première contient le front.*
2. *La seconde le nez.*
3. *La troisième la bouche et le menton.*

Depuis le menton jusqu'à la fossette qui se trouve entre les clavicules, on compte deux longueurs de nez.

De la fossette, qui est entre les clavicules, au bas des mammelles, une face.

Du bas des mammelles au nombril une face. On observe que l'Apollon a la mesure d'un nez de plus.

Du nombril aux parties naturelles, une face. L'Apollon a encore dans cette dimension un nez de plus.

Des parties naturelles au dessus du genou, deux faces. On observe que le milieu du corps de la Vénus Medicis se trouve au dessus des parties naturelles, et Albert Durer le place ainsi dans les proportions qu'il prescrit pour les femmes, ce qu'approuve de Piles.

Le genou contient une demi-face.

Du bras de genou au coup de pied deux faces.

Du coup de pied au dessous de la plante une demi-face.

L'homme étendant les bras, est (si on le mesure du plus long doigt de la main droite à celui de la main gauche) aussi large qu'il est long. (Plate iv. fig. 8.)

D'un côté des mammelles à l'autre deux faces.

L'os du bras dit humerus *est long de deux faces depuis l'épaule jusqu'au bout du coude.*

De l'extrémite du coude à la première naissance du petit doigt, l'os appelle cubitus *avec partie de la main, contient deux faces.*

De l'emboîture de l'omoplate à la fossette d'entre les clavicules, une face.

Il faut observer que la différence qui se trouvera entre la largeur et la longueur du corps provient de ce que les emboitures du coude avec l'humerus, et de l'humerus avec l'omoplate, emportent une demi-face, lorsque les bras sont étendus.

Le dessous du pied est la sixième partie de la figure.

La main est la longueur d'une face.

Le pouce est la longueur d'un nez.

Le dedans du bras, depuis l'endroit où se prend le muscle qui fait la mammelle, appelle pectoral, *jusqu'au milieu du bras, quatre longuéurs de nez.*

Depuis le milieu du bras jusqu'à la naissance de la main, cinq longueurs de nez.

Le plus long doigt du pied a la longueur d'un nez.

Les deux bouts des mammelles et la fossette d'entre les clavicules de la femme, font un triangle equilatéral parfait.

Article de M. Watelet *sur proportion. Encyclopédie Méthodique. Beaux Arts.*

The Laws of Outline being common to Sculpture and to Painting, the following, from our own Flaxman, will be found no less useful than those of the above-named celebrated foreigner.

From the os pubis to the top of the head, one-half the length of the human figure.

From the same point to the sole of the foot, the other half.

From the acromion of the scapula to the bottom of the inner ankle there are three equal divisions. 1st. From the acromion to the point in the spine of the ilium, from which the rectus and sartorious muscles begin. 2dly, From thence to the top of the patella. 3dly, From the top of the patella to the bottom of the inner ankle.

From the bottom of the pubis to the bottom of the patella is the same length as from the bottom of the patella to the sole of the foot, two heads each; but we must observe, the Ancients generally allowed half a nose or more to the length of the lower limbs exceeding the length of the body and head.

Breadth.

Shoulders	2 heads.
Loins	1 head and 1 nose, or 5 noses.
Across the hips or trochanters	1 head 2 noses, or 1 head and ½.

Depth.

Chest	1 head 4 minutes.
Loins	3 noses and ½.
Glutæi	1 head.

Breadth of the Thigh.

Thigh..............	3 noses.
Calf of the leg	2 noses.
Foot	1 head and ½ of a nose long.

Length of the Arm.

From the top of the humerus to the bend of the arm	1 head and ½.
From the bend of the arm to the first knuckles ...	1 head and ½

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cases might be named in which they would destroy the truth and spirit of an historical picture. It would be as absurd to adapt the features of the Belvedere Apollo to the head of Socrates as it would to place the head of a dancing fawn upon the shoulders of Alcibiades. But where neither History nor Tradition have confined the Painter to a given set of features, he has opportunity of introducing such forms and proportions as unquestionably assist, though they do not constitute expression. Gracefulness, and the bodily signs or movements of intellectual beauty, are much more various than is commonly imagined.* Their number defies calculation. Their forms once discovered and attained may be measured and will be found symmetrical. But they are not attainable, that is, they are not discoverable by rule and compass. They baffle the mere copyist.* Yet without them all that Outline can do is mean, insipid, and powerless. How often do we see, in living subjects, limbs of fairest proportion that betray vulgarity and awkward unfitness for the part assigned them; and faces in which, though worthy to have been modelled in a Grecian mould, it pains us to discover no intelligence. The female form, above all, provided feminine expression be wanting, may be made as perfect in proportions as the chisel or the pencil can shape it; but the subject will not be beautiful, as far as intellectual beauty is concerned.

Of Outline.

Employment of the limbs and muscles upon posture and locomotion.

(266.) We have now considered the animal frame with respect to its proportions, and their general aptitude for characteristic expression. But we must not quit the subject of Outline without remarking likewise upon the aptitude of animal forms for the various modes of progression or of rest peculiar to each. We need scarcely exhort the student to this deeply interesting study, as containing the most indispensable rudiments in the grammar of his Art. We desire our imperfect notice of it to be regarded as only pointing to the arduous road which his perseverance is to surmount. The varieties in this division of our subject are so numerous and complicated, that they drive brevity to despair, and bid defiance to classification. But we confine ourselves to the twelve following. 1. Standing. 2. Sitting, kneeling, or reclining. 3. Rising from a seat or from a recumbent posture. 4. Walking. 5. Running. 6. Dancing and leaping. 7. Climbing. 8. Pulling downwards, upwards, or horizontally. 9. Pushing in three similar directions. 10. Carrying weights. 11. Throwing any weight. 12. Falling.

(267.) Previously to our notice of these particulars, it will be necessary to refer the reader to our pages on MECHANICS, and to remind him that within every substance or combination of substances, such as, in the present instance, any animal body, there is a point termed the *centre of gravity*, round which all the parts of a body balance each other, and through which, if a plane pass, the segments on each side will be of equal weight. With this point, or centre of gravity, once supported, the material substance remains balanced in any position. And the support may be given in two ways, either 1st, by suspending the substance from a *line* attached indifferently to any part of it; and in this case, the line by which it hangs being produced downwards, will contain in it the centre of gravity (MECHANICS, p. 34. sec. 116.) *below* the point of suspension. Or, 2dly, the support may be given by a prop from below,

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Breadth.

Upper arm, front view	1 nose and ½.
Upper arm, side view	2 noses.
Lower arm, thickest part.......	1 nose and ⅓.
Wrist	1 nose.

The female figure should not be so tall as the male, the shoulders and loins should be narrower and the hips broader. The proportions of the Hercules Farnese and the Torso Belvedere, are nearly one-fifth more in breadth than those of other statues; but the Ancients varied the proportions according to the character and age of the person. There are examples of the Silenus and Hercules also, when he partook of the same character, extremely dwarfish, not exceeding four or five heads in height; and there are examples on some of the Greek vases of figures nine or ten heads high. *Lectures*, p. 30. The reader who desires an extensive examination on this subject may consult a publication (dedicated at Milan, 1811, to Canova,) by Giuseppe Bossi, and entitled *Discorso delle Opinioni di Lionardo da Vinci intorno alla Symmetra de' Corpi Umani.*

* The features of the human face, together with the forms and proportions of the body and limbs are, in particular Countries, subject to certain peculiarities, an agreement with or material deviation from which constitutes the local idea of beauty or deformity. The sculptors of ancient Greece seem to have diligently observed the forms and proportions constituting the European ideas of beauty, and upon them to have formed their statues. A slight deviation from these measures, by the predominancy of any feature, constitutes what is called *character*, serving to distinguish the owner thereof, and fix the idea of identity. This deviation or peculiarity aggravated, forms *caricatura.* See *An Essay on Comic Painting* in the *Antiquarian Repertory*, vol. i. p. 13. By F. Grose, F. A. S.

What Mr. Grose here applies to identity of person may also be affirmed respecting identity of expression. There are portions of the figure, the outlines of which are more or less adapted for expressing peculiar passions and sentiments, or peculiar endowments of the individual. A certain part of the face, for example, must be allowed its due proportion for the play of certain muscles indicative of certain intellectual or animal impressions and sympathies. Some features are best adapted for expressing fear, grief, anger, scorn, or jealousy; some for laughter and uproarious triumph; others for the serener qualities of meditation, of tenderness, of esteem, and the peaceful affections. A large mouth and large lower jaw indicate animality. In proportion, therefore, as the forehead is increased, the comparative size of the lower part of the head appears diminished and animality less indicated. This seems a good and sufficient reason for the Greek proportions. The lower half of the face could not be diminished without evident deformity, since, to be human, it must bear a certain proportion to the adjacent neck and shoulders. It remained, therefore, for the Greek artist, as his only alternative, to increase the upper portion of the head, preserving at the same time its oval form. The reader on this subject will find many judicious observations in Hogarth's Essay above quoted, which, though below criticism in regard to literary merit, contains much practical knowledge. "The Antinous," says he, "being allowed to have the justest proportion possible, let us see what addition upon the principle of quantity can be made to it without taking away, at the same time, any of its beauty." He then observes that an addition of dimensions to so beautiful a head would deform it; to the hands or feet would be gross and vulgar; to the length of the arms, would be dangling and awkward; to the length or breadth of the body, would be heavy and clumsy. The neck alone and the inferior extremities remain, to which he finds that not only certain additions may be admitted without a disagreeable effect; but that a greatness or dignity (conspicuous in the Apollo Belvedere) may be given to an already graceful human form. Much more may be read and collected on the same subject throughout the ingenious pages of Lavater, the contemporary of Hogarth, who at the time the latter published the analysis, was in his twelfth year. The work of Lavater coming from a man of erudition and very cultivated genius, is not so remarkable as the analysis of Hogarth, who, though the son of a schoolmaster, appears to have been as self-taught as Shakspeare is presumed to have been in *literis humanioribus.*

* Reynolds observes of Gainsborough, that he was certainly not indebted for grace and elegance to the Flemish School, nor indeed to any School. His gracefulness was not academical or antique, but selected by himself from the great school of Nature. And there are yet, adds Sir Joshua, a thousand graceful modes which are neither theirs nor his, but lie open in the multiplied scenes and figures of life to be brought out by skilful and faithful observers.—*Works*, vol. ii. p. 162.

in which case the line of the sustaining force must be directed upwards, (as the line of suspension was downwards,) perpendicularly to the horizon, and being produced, will contain the centre of gravity *above* the fulcrum or sustaining point.[*]

ine of di- ction or gravita- n.

It is also to be recollected, that whatever be the number of these suspending cords affixed to the given point of attachment, or whatever the number of supporting fulcra at a point under the incumbent weight, a perpendicular line through the centre of gravity to the point of suspension above, or to the plane of the horizon below, will always express the *direction* in which the several suspending or sustaining forces must, to secure a balance, be applied. This *line of direction*, or of gravitation, as we prefer to call it, must fall within the base of any figure, that would be preserved from the fate of the unstable balance, or in other words, must fall within the line or lines joining the several points at which the supporting fulcra or props rest on the ground.[†]

(268.) Another circumstance to be borne in mind is, that in the case of any thing added to the weight of a body, the centre of gravity varies its position within the combined mass, and moves towards the side where the addition is made. Hence it happens, that the centre of gravity in the human subject (as in all animals) varies according to the size and form of the bones, and the degree of fatness or leanness[*] prevailing in any particular part; also according to the addition of any appended substance, as clothes, armour, burthens, &c. But it will commonly be found in or near the acetabular line.[†] We proceed to take each case in the order proposed.

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[*] The former of these two modes is called the stable balance, because the centre of gravity, whatever changes the body may undergo, will always take a position of stability under the point of suspension. Whereas, in the second mode, (called the unstable balance,) the centre of gravity will, at any the slightest variation in the weight supported, remove from its place above the *point d'appui*, and descend to take the lowest position.

[†] Let us survey the human structure architecturally. We see two pillars, each supported upon three arches, and above each pillar a beam attached by a hinge-joint, manageable by ropes and pullies. These two beams, at their upper ends, are placed under two arches, which unite at the back of the building, and support a large column. The column is of peculiar workmanship, being capable of bending to form a crane, or of being turned about in some degree like a revolving mast, and having two hanging towers suspended from it, the lowermost of which carries at each side certain projecting timbers, which like the yards of a ship (and more particularly the mizen gaff) may be raised or depressed at pleasure. From this mechanical sketch of the human body, the difficulties of preserving equilibrium in a fabric so complicated are manifest. In the instance of quadrupeds, where the body may rest or swing at its full length, upon four supporting pillars, there appears less danger of a fall. But in Man, with an erect head and trunk, resting one end upon two supports, that measure at least half his height, and upon a base which, when he trusts (as he must continually do) to one foot, is no broader than one-tenth of his height, a fall seems inevitable.

Such a view of zoological architecture, if we may so phrase it, may help the observer to remember universally that each limb has its own centre of gravity, and that whether it is moved by, or is a mover of the main body or of other limbs, it will, according to the position of its own centre of gravity, be more or less easily manageable. "The differences which we discern in the muscles of the lower extremity between Man and the other mammalia, arise out of that characteristic feature, which so strikingly distinguishes Man from all other animals, *viz.* his erect stature. In order to enable any animal to preserve the erect position the following conditions are required: 1st. That the parts of the body should be so disposed as to admit of being maintained with ease in a state of equilibrium; 2dly, that the muscles should have sufficient power to correct the deviations from this state; 3dly, that the centre of gravity of the whole body should fall within the space occupied by the feet; and, lastly, that the feet themselves should have a broad surface, resting firmly on the ground, and should admit of being, in a manner, fixed to the earth. All these circumstances are united in the necessary degree in Man only. The broader the surface included by the feet, the more securely will the line of gravity rest within that surface. The feet of Man are much broader than those of any animal, and admit of being separated more widely from each other. The sources of the latter prerogative reside in the superior breadth of the human pelvis, and in the length and obliquity of the neck of the femur, which, by throwing the body of the bone outwards, disengage it from the hip-joint. The whole *tarsus*, *metatarsus*, and *toes* rest on the ground in the human subject, but not in other animals. The simiæ and the bear have the end of the os calcis raised from the surface; while, on the contrary, it projects in Man, and its prominent portion has a most important share in supporting the back of the foot. The exterior margin of the foot rests chiefly on the ground in the simiæ, which circumstance leaves them a freer use of their thumb and long toes in seizing the branches of trees, &c.; and renders the organ so much the less adapted to support the body on level ground. The breadth of the human pelvis, also, affords a firm basis on which all the superior parts rest securely; the same part is so narrow in other animals, that the trunk represents an inverted pyramid; and there must consequently be great difficulty in maintaining it in a state of equilibrium, if it were possible for the animal to assume an erect position. In those instances where the pelvis is broader, the other conditions of the upright stature are absent; the bear, however, forms an exception to this observation, and admits of being taught to stand and walk erect, although the posture is manifestly inconvenient and irksome to the animal. The perpendicular position of the vertebral column under the centre of the basis cranii, and the direction of the eyes and mouth forwards would be as inconvenient to Man, if he went on all fours, as they are well adapted to his erect stature. In the former case he would not be able to look before him; and the great weight of the head, with the comparative weakness of the extensor muscles, and want of the ligamentum nuchæ, would render the elevation of that organ almost impossible. When quadrupeds endeavour to support themselves on the hind extremities, as for instance, for the purpose of seizing any objects with the fore feet, they rather sit down than assume the erect position. For they rest on the thighs as well as on the feet, and this can only be done where the forepart of the body is small, as in the simiæ, the squirrel, &c.; in other cases, the animal is obliged also to support itself by the fore feet, as in the dog, cat, &c. The large and strong tail, in some instances, forms, as it were, a third foot, and thereby increases the surface for supporting the body, as in the kangaroo and jerboa. Various gradations may be observed in the mammalia, connecting Man to those animals which are strictly quadrupeds. The simiæ, which are by no means calculated for the erect position, are not, on the other hand, destined like the proper quadrupeds to go on all fours. They live in trees, where their front and hinder extremities are both employed in climbing, &c." Blumenbach's *Manual* by Lawrence, p. 309.

[*] In corpulent persons it has a tendency forward, which obliges them to throw back the head and shoulders and upper part of the spine to balance the obesity in front. This gives a consequential air, often bordering on the ludicrous, to fat people. On the contrary, in persons bending or stooping forwards, there is required to balance the protrusion of the upper part of the trunk a proportionate removal backwards of the nether part of the spine and loins. In proof of this, let the reader stand with his heels close to a wall, and endeavour to make a bow. Also in persons stooping sideways to pick up any thing. the overhanging of the head and arm on that side must, in order to avoid a fall, be counterpoised by a corresponding extension on the other, of the arm, or leg, or haunches. Again, in like manner, among persons with a weight on one shoulder, their centre of gravity has a tendency to the loaded side, and would draw the line of gravitation out of the base, but for the exertion of the carrier, who inclines his head and thorax proportionably to the side opposite.

[†] This was the calculation of Borelli. We have given under MECHANICS, page 34. sec. 116, some methods of finding by experiment the centre of gravity in any substance. If the substance be successively suspended by several points and pierced by straight lines, in each case passing, in a vertical direction, through the point of suspension, it would be found that however numerous those lines might be they would all intersect in one point, which would be the centre of gravity of the body. Borelli ascertained that of the human body by one of the methods we have given: namely, by means of a wedge or prism. He thus explains himself. *Extensa*

1. Employment of the limbs and muscles in standing.

1. First, then, to consider the human figure in a standing posture. In order to represent a balance, there must be conceived to pass through the centre of gravity, a vertical plane dividing the mass to be supported into two equal portions. (Art. 267.) The base also of the supporting fulcra beneath must receive within it the line of direction or gravitation. As the simplest kind of example, let us suppose a figure standing perfectly still, and resting equally on both his feet, with the hands and arms pendent on each side. In this attitude each leg sustains an equal weight, impending on it from the body; and the pit of the sternum, between the claviculæ, hangs perpendicularly over the feet in a line of gravitation, of which the lower extremity touches the ground between the inner ankles. The mesial plane (Art. 226.) contains this line, and will bisect vertically the whole frame from the forehead downwards.* This, however, is not the ordinary position in standing. It requires effort, and becomes wearisome. To ease the muscles, the centre of gravity is removed to one side and placed over one foot.† For this purpose, the spine of the back is inflected to the side in question, and conveys so much of the head and shoulders over the supporting limb as will be necessary to balance the figure; which may again be equally divided, as before, by a plane passing through the centre of gravity, though not now the mesial plane.‡ This is the easy, unconstrained position of the Antinous, the Venus de Medicis, the Hercules Farnese, and others of the finest sculptured forms.*

2. Sitting, kneeling, reclining,

(269.) 2. Sitting, kneeling, or reclining. The only difference between the balance here to be represented and that already described is, that a greater number of supports are given to the body.†

A sitting posture may be varied *ad infinitum*.‡ Its

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homine nudo super tabulam planam in ejus medio supposui cuneum prismaticum triangularem ad fulciendam tabulam perpendiculariter in ejus centro gravitatis. Hæc tabula quiescebat æquilibrata quotiescunque fulcimentum cunei in puncto existente inter nates et pubem hominis super tabulam jacentis, pertingebat. Quare centrum gravitatis illius hominis in illo situ existebat. Pars 1ma. lib. xviii. *De Statione Animalium*, prop. 134.

* First of all, (to begin from below,) the gemellus, the solæus, the tibialis anticus, the peronei, the flexors of the toes, (Art. 256,) together with the lumbricales and interossei (Art. 245) pedis, plant each foot firmly on the ground. Next, each leg is kept steady in *front* by the extensors of the toes, by the peroneus tertius, and in some degree by the tibialis anticus; (Art. 256;) on its *outside* each leg is held up by the peronei longus and brevis, (*Ib.*) on its *inside*, by the tibialis anticus and posticus; (*Ib.*) and *posteriorly* by the gemellus and solæus, the semitendinosus, and the flexores longi. (*Ib.*) Four extensors (Art. 255) stretch the knee-joint, partly assisted by an occasioned flexor, the tensor vaginæ femoris. (*Ib.*) Next above these limbs, the balance of the trunk upon the heads of the femora is to be maintained: in front, by the sartorii, the recti, the psoæ, and the iliaci interni; (Art. 254;) posteriorly by the bicipites, the semitendinosi, and semimembranosi; (*Ib.*) externally by the glutei and tensores vaginæ femoris; (*Ib.*) and internally by the pectinei, the adductores femoris, and the graciles. (*Ib.*) Lastly, to keep the vertebral column erect, we have numerous muscles on the back, (Art. 253,) which greatly exceed in power those in front, (Art. 252,) in order that they may sustain the weight of the thorax and abdomen suspended upon them. In old age they lose their vigour, the back is drawn down and bended forwards. The sacral extremities, to compensate for this, are thrown back, and the knees inflected; until at length a staff becomes a necessary support. The same observation may be applied to the equilibrium of the head. The muscles for preventing its inclination forwards are much the strongest.

† The muscles are much fewer, and the muscular effort considerably less for standing on one extremity only than for a station upon two. To prevent the supporting limb from being drawn inwards, (or in a tibial direction,) its outward muscles are strongly contracted, as long as the centre of gravity is in transitu from the other limb. The leg or tibia (of the supporting limb) is accordingly drawn outwards by the peronei, (Art. 256,) by the vastus externus, and also partly by the rectus; (Art. 255;) while the weight of the superincumbent pelvis, with that of the body over it, are transferred (also outwards) by the tensor vaginæ femoris (Art. 254) and the glutei medius and minor. (*Ib.*) Thus the muscles of one side only become thrown into action, and their power is simply balanced by a portion of the weight of the body towards the other side.

‡ Da Vinci, who though a skilful anatomist, was superior to all anatomical display in his Art, has left many useful rules in his Treatise on Painting respecting the equilibrium of the human body. He divides it into simple and compound. Simple equilibrium is exemplified when a man sustains only his own weight. In this situation, if the man stretch out an arm or both arms, or stoop forward, or stand erect, supporting his body on one foot, his centre of gravity will be found in a line perpendicular to the centre of that foot on which he rests, or, if his body rests equally on both feet, the centre of the trunk will lie perpendicularly over a base line joining the centres of the two feet. Compound equilibrium he explains to be that of a man carrying a burden: as, for example, the Hercules lifting up and crushing Antæus, where an equivalent to the weight of Antæus is caused by throwing back the upper part of the body of the hero behind the base line that connects his feet. See *Trattato della Pittura*, cap. 263. In another passage he observes, that the weight of the hand, when one arm is extended, has the effect of a weight at the end of a steel-yard; and that to preserve an equilibrium there is frequently a necessity of raising and suspending the heel on the opposite side, which thus obtains a counterpoise equivalent to the increased weight given to the arm and hand by their extension, cap. 350. See also cap. 201—204 and cap. 264.

* In standing, the legs naturally relieve each other, and thus divide the labour of supporting the body. A jaded horse will be often found resting the whole weight of his hind quarters upon one hind leg, while the other lifted and inflected hangs at rest and at liberty to recruit itself. The well-known position of a soldier standing "at ease" is adopted upon the same principle of alternation, which seems to pervade corporeal motions generally. Butler in his *Hudibras* thus describes the mutual good-will subsisting between the right and left leg:

———— in running, every pace
Is but between two legs a race,
In which both do their uttermost
To get before, and win the post;
Yet when they're at their race's ends
They're still as kind and constant friends,
And to relieve their weariness,
By *turns give one another ease.*

We may here add, that the necessity for removing the centre of gravity in these cases directly over the supporting limb may be easily proved by any person attempting to stand on one foot, with its outer ankle touching the wall of a room. Such an act will be found impracticable. The wall is in the way, hindering the transmission of the centre of gravity to its proper place over the foot in question. (See second note to Art. 268.)

† In order to afford himself at any time an example of a reclining posture, the student need only sketch a figure in which the weight on one side has not been counterpoised by an equal weight on the other; a figure, consequently, of which the line of direction or gravitation falls without the base. Then on the same side with the line of gravitation, and still further without the base, let him place some new fulcrum or support: taking care that a line drawn from its point of contact with the ground to the points of contact of the other fulcra, shall include that line of direction. The figure, for example, of an old man to be drawn leaning on a staff would bend forward or to one side, having no strength to throw out a proper equivalent for balancing it on the side opposite. Consequently, his staff is necessary to his support, and must be so placed as that lines from its point of contact with the ground drawn to each of his feet shall form a base to include the line of gravitation. It is manifest that a figure leaning against a tree, a wall, a pillar, &c. must have its design or outline regulated by the same principle. The draughtsman must also exercise his judgment to express the due proportion of weight sustained by each leg, after deducting that quantity supported by the additional prop. In the act of kneeling on both knees, the line of gravitation must fall between them unless the shins or toes touch the ground, in which case it may fall any where between the femora. If only one knee be employed for support, lines drawn from it to the foot of the other leg, will give as before, the base of the figure. But if the hands or elbows form additional props, these also must be reckoned for, and lines accordingly drawn to form a base in the manner already suggested.

‡ In the sitting posture, observe that the centre of gravity common to the whole body is brought near to the base, but that the

simplest outline is that of a child resting almost solely on the os ischium, with its legs left to play at liberty, suspended from the acetabula, and with its trunk and superior extremities suspended from the vertebral column. To this lively subject may be presented a contrast as opposite as elastic childhood is to infirm and rigid age; namely, the case of sitting in an elbow-chair, with one side of the body or both supported by the aid of the ossa humeri, while the lower limbs, by alternate inflection or extension of the knees and feet, lend assistance to the torso. Here all that seems material to the representation of a just equilibrium, is that the chair or seat be firmly and evenly balanced, and not in the position represented by Hogarth in the chairing of his successful candidate.*

Rising
om a
at, &c.

(270.) 3. Rising from a seat, or from a recumbent posture. On the attitude of a person intending to rise from his knees, Da Vinci observes, (*Trattato della Pittura*, cap. 237.) that his first effort is to relieve one knee by removing his weight (or superincumbent centre of gravity) entirely over to the other knee. The leg at liberty having then no weight to lift but its own, raises its knee without difficulty, and plants its foot upon the ground. This operation over, the man, resting his hand upon the elevated knee, lifts his arm, head, and chest towards that side, and thus contrives to shift his whole weight over back again upon the firmly planted foot. On this foot as a fulcrum, and by means of its thigh-bone as a leaver, he raises himself. His body, in rising, draws up after it the inflected leg which, during the ascent, gradually extends itself till it stands upright beside the other.† The student will see that by giving the assistance of the hands or of other additional fulcra, this action may be varied in innumerable ways; and that the body while rising from any recumbent posture must be balanced in a similar manner.

4. Walking.

(271.) 4. Walking. This action, in the human subject, is the transfer of the line of gravitation (Art. 267.) alternately from one leg to the other, and during the transfer a simultaneous motion forwards propelling the common centre of gravity.* In this progressive process

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centre of gravity common to the head, trunk, and upper members, is at some point between the regions of the abdomen and thorax. The line of direction therefore from this point must fall within a base between the ossa ischii, else the trunk to be kept from falling will require to be suspended by the action of the strong dorsal and lumbar muscles attached to the back of the ilium, while that bone is kept steady by the antagonizing femoral muscles in front aided by the weight of the femora and legs. This will happen during an inflection of the spine sideways or backwards, but not forwards, in the same degree, unless in addition to the fulcra of the ossa ischii such a portion of the femora (as when the subject is seated in a chair) be added as will enlarge the base sufficiently to incline the line of direction. Note also, that in stooping to the right or left while the body rests on only one of the ossa ischii, a similar balance must be effected, as in the case of standing upon one foot. The only difference is, that in this case the leg is no longer a supporter, but is altogether a librator. If the sitter in stooping bend his body to the right, the left leg must be stretched proportionally to the left, and *vice versâ.* In this example, observe that the sitter is not permitted to hold by the chair or seat, which would be altogether a different case, and might be classed as a modification of climbing.

* In the reclining posture of the celebrated statue called by some the Dying Gladiator, and by some the Dying Soldier who brought news to Athens of the victory at Marathon. (Plut. *de Gloria Atheniensium*, vol. ii. p. 347.) The figure is supported by the right femur and part of the fibular side of the right leg. But as the body leans over to the right this base would be insufficient, since the line of direction falls without this base, and consequently the trunk would come to the ground but for the right arm, which being extended to the right beyond the line of direction, enlarges the base and forms a sufficient prop for the body. The left leg and left arm are at the same time extended to a certain degree, and form a counterpoise on the left side to the opposite inclination of the head and thorax. Observe in this statue an example of our remarks (notes to Art. 242) on drawing breath. The shoulders of the wounded man are raised, and the best position chosen for receiving air during the accumulation of blood which evidently keeps flowing within him, and must terminate in death.

One of the most graceful antique specimens of a recumbent figure is among the Elgin marbles; that of the "Ilissus," called by some the "Theseus."

† We extract the following from Barclay, *On Muscular Motion*, p. 290. "In rising from a chair, the centre of gravity must fall within the base upon which we are supported; and therefore this centre, by the inclination of the body or otherwise, must be brought to the base, the base brought to the centre of gravity, or both made to meet by mutual approach. Hence, in rising from a chair or sofa, where the femur and tibia were at right angles, the feet are drawn back, or the body is thrown forward, before we can assume the erect posture. In the changes of attitude while a bone is turning on its centre of motion, the centre itself is often at the same time describing either the segment of a circle, or a line composed of the segments of circles. Suppose A B (plate x. fig. 2.) represents the foot, B C the tibia, C D the femur, and D E trunk, and that the three last are to be brought by the action of their muscles to the perpendicular B F, so that B C shall occupy the situation of B G, C D the situation of G I, and D E the situation of I F; the point C on the centre B will move in the segment C G, and as C is changing its position in C G, the point D, which moves round the point C as its centre, will, if the extensions be regularly performed in the same time, describe such a curve as D I; for as the point D must necessarily move atlantad, (upwards,) and sternad, (forwards.) in order to preserve the centre of gravity, the general direction of its course must be known; and if C G be divided into equal parts, and at each of the divisions a circle described with the radius C D, the points in D I corresponding in number with the points in C G, and at equal distances in the sternal (forward) direction will each be found in the circumference of one of the circles described successively round the point C as it passes along the segment C G. In like manner, if the extensions of C D and D E be regularly performed in the same time, the point E will describe such a curve as E F, the points in E F being in the circumferences of the several circles successively described round the point D as it moves along the curve D I."

The author then proceeds to observe that the above figure explains also how the rapid extension of the several joints may carry the body directly upwards; the motions are backward and forward alternately, but all of them upward. If, therefore, the backward and forward motions be made to balance exactly their forces, the upward movement only will remain. On the other hand, if the respective motions backward and forward be equal in force, the body at the same time that it rises will have an inclination forward or backward in the direction of the prevailing force. (See MECHANICS, *Composition and Resolution of Forces*, sec. 19—27.)

That his illustrations might be less complex, Dr. Barclay supposes for the while the vertebral column to continue inflexible, and by its extension on the point D to be capable of forming a straight line with the femur and tibia. On this supposition, if a force were applied to the point F, it would press directly through the medium of the trunk on the femur and tibia to the point B. "But," he adds, "as the supposition is without foundation in nature, and as no two bones are ever known to form straight lines, or to be united by parallel surfaces of articulation, the pressure which one bone makes upon another must always be oblique. This causes them to turn on their centres of motion, and as their centres of motion are movable, to diffuse the pressure generally and suddenly through the whole system, and thus counteract with admirable contrivance the dangers of concussion. The curves D I and E F are merely the curves which bones describe in particular circumstances. With the assistance of movable centres, the bones, if properly directed, may be made to describe any species of line whatever, as must be evident from the motions of the hand, which has the power of following any line straight or curved that can possibly be drawn."

* The first motion in the standing figure throws the weight on one leg. The gravitating line falls, in consequence, from the gullet on that one leg, the shoulder on the same side being lowered, the shoulder on the opposite side raised, while the hip and knee sink below those of the side which supports the weight. Flaxman's *Lectures on Sculpture*, p. 127. But we will here translate from Borelli a more detailed description. At first view, says this venerable and often quoted authority, the progressive motion in Man may seem to resemble that of the pair of compasses B A C (plate iv. fig. 4.)

the arms are often as actively employed in balancing,* as the legs are in lifting and moving the body onwards.† While the body is balanced on one leg, the other is propelled by contracting the gemellus, the solæus, the semitendinosus, the tibialis anticus, and the tibialis posticus. The tibia is, at the same moment, raised by the extensors of the knee while the entire leg is lifted and extended by the psoas, the iliacus, the pectinæus, the triceps adductor, the sartorius, and the gracilis, aided by the tensor vaginæ femoris.* Observe also, (Da Vinci, cap. 208. 295. 299.) that in proportion to the speed of the walker his line of direction or gravitation will be found to fall more or less forward. A slow pace will require it to lie very little forward. But it must lie considerably forward in a person walking swiftly or against the wind.†

5. Running.

(272.) 5. Running. The centre of gravity‡ is here

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placed erect upon the plane of the horizon, and forming in that erect position the isosceles triangle A B C. Raise the foot C until the line of gravitation A D coincides with A B, which we may call the line of support, (*linea innixionis,*) and which then becomes perpendicular to the horizon. Then round A B as an axis let the limb A C describe the portion of a cone A C E. Next, having planted the limb A C in E, again raise the compasses until A E becomes perpendicular to the horizon. Let now the other side A B revolve, describing the arc B F, and in this way, by alternately making with one limb a perpendicular to the ground, and with the other a circular movement, a sort of progression may be produced. But as this mode of walking would have been equally unsightly and troublesome, Nature has provided for the machine of the human frame a plan of locomotion much easier and more graceful. Let, for instance, the feet of a man, standing, form at the points where they touch the ground, the isosceles triangle A B C. (Plate iv. fig. 5.) To change him from this fixed state, the lever or column of the foremost leg A B is made to revolve round a centre B in a plane perpendicular to the horizon, while, at the same instant, the entire frame R of the body is impelled forward in the direction K. These combined movements are effected as follows. When the foot L C becomes extended by the action of the solæus muscle, the angle A L C becomes an obtuse angle, and since the apex of the foot touches the ground at the point C, the length of the whole leg and hip is increased by the addition of C L, the length of the foot. During this process, the isosceles triangle above described alters its form and becomes a right-angled triangle at the moment when the leg A B stands perpendicularly on the horizontal plane. During this well-known movement the entire frame R being supported by two feet may easily be made so far to incline forwards, as that the leg A B may form a perpendicular support. By the very act also of extending the foot and the consequent elongation of A C, the ground receives a stroke from the apex C of the foot. The reaction arising from this impulse urges the machine R forward in the direction K, just as a barge impelled by a pole in the hands of a waterman is separated from the bank of a river. The impulse above described is materially assisted by a slight inclination forwards of the head and thorax towards K. By this movement the centre of gravity of the whole body, and consequently the line of gravitation, being brought outside the confines of the foot B O, exposes the whole to the risk of falling; and thus, by the law of gravitation, (*sponte suá,*) and without further muscular effort, the weight of the frame R will be made to change its place. The danger, too, of falling is quickly provided against by raising the foot L C, and transferring it forwards with a brisk motion to K, beyond the limits of the line of gravitation. This done, the body returns to the station of firmness and safety in which it was originally supported; and by repeated renewals of the process above detailed, is maintained in a state of progression. *De Gressu Bipedum*, pars 1ma. prop. 156.

* Da Vinci instances the case of a person walking on a rope, who balances himself without a pole by means of his extended arms, cap. 198. Also see cap. 202. 208. 350. In a great number of animals, observes Dr. Barclay, that length of neck which is necessary for procuring their food, is regularly employed by the same animals in balancing their system: and even the most careless observer may have seen that birds employ it in changing the centre of gravity from their legs towards their wings, or from their wings towards their legs, according as they choose to walk or fly. p. 294. Butler in his picture of Hudibras, adheres with ludicrous accuracy to the laws of libration.

His back or rather burden showed
As if it stooped with its own load,
To poise which equally he bore
A paunch of the same bulk before,
Which still he had a special care
To keep well crammed with thrifty fare, &c.

† This is the duty of the solæus muscle acting by its tendon (tendo Achillis) upon the lever of the foot. We need scarcely remind the reader that the contracting power of a muscle is always nearest to that part of it termed its origin, and furthest from that part called its insertion: nor that the bones are acted upon by the muscles as levers are by a given mechanic power. Of the three levers (see MECHANICS, sec. 138. p. 43.) examples to our purpose may be easily given. 1. In levers of the first kind, (with the fulcrum between the power and weight as in the application of a crowbar,) we have an example in the movement of the head forwards and backwards upon the first of the cervical vertebræ, which forms the fulcrum or centre of motion on either side of which the mastoid and the occipital muscles are alternately opposed to the head's weight. Another example is seen in the act of straightening the body, or lifting it up after having inclined it forwards in making a bow. The power is in the muscles attached to the os ilium, the fulcrum is in the pelvis, (or rather the fulcra are the points where the acetabula rest on the bones of the femora,) and the weight is the upper part of the body which has been previously inclined forward. 2. The second kind of lever when the weight is between the fulcrum and power is exemplified in the act of standing on tiptoe. The power is in the muscle (solæus) at the back of the heel. The weight is that of the body over the arch of the foot, and the props are the toes. This lever is also constantly employed for propelling the centre of gravity in running or walking. It is exemplified in the legs of birds and in the hinder legs of quadrupeds. 3. The third kind of lever with the power between the prop and weight is most common. It is shown in raising a weight on the palm of the hand, and bending the arm at the elbow-joint. The power of the biceps muscle acts between the hand and elbow. (Art. 243, 244.) This kind of lever is used perpetually in the limbs. And although, of the three, it incurs the greatest expense of power, that disadvantage is compensated by the additional celerity it affords.

* If we conceive the left leg to be thus raised and propelled, (as that of an infantry soldier preparing to march,) it is now ready to plant itself before the right at the usual interval of a foot's pace, and under the centre of gravity, which meanwhile has been urged forward and downward by the psoæ and the iliaci interni, in conjunction with the recti and obliqui abdominis. The left knee is here for an instant slightly inflected, the better to receive the incumbent weight, and then the right limb, with its toes forcibly pressed by their flexors against the ground, proceeds to repeat a similar succession of movements as soon as the left leg becomes in its turn firmly stationed.

† It is further to be noticed, that in all biped animals, whether men or birds, a remarkably characteristic depression and contraction take place on the side to which the supporting limb belongs, while on the opposite side we see a corresponding elevation and elongation; the humerus raised, the hip and knee lowered. The height of quadrupeds also varies in the moving animal more than in the same animal at rest. Their legs first touch in an oblique direction, but afterwards being extended in propelling the body, they are brought to make perpendiculars with the horizon, and must in doing so, elevate the parts immediately above them. Da Vinci, *Trattato della Pittura*, cap. 195. 249. 268. 199.

‡ The centre of gravity, in the progression of the human subject, may be compared to a ball shifted alternately from one hand to the other, while the hand that is to receive the ball keeps continually advancing. In like manner, the legs, or abdominal extremities, advance alternately in pursuit of the centre of gravity, which may be said to be *handed* over from one side to the other, and which in proportion as the head and shoulders incline further forward, requires to be pursued and caught up with the greater swiftness and promptitude by the limb below. Care, however, must be taken, that the centre of gravity, in running, be only inclined in such a direction forwards, that the suspended foot may plant itself favourably under it in order to progression. Otherwise there will be the appearance of either staggering or falling. Let the student never fail to observe throughout every movement or posture of the body that the curves of the spinal column cooperate with the flexure of the supporting limb or limbs to balance the whole system. The changes of position, Dr. Barclay well observes, are never accidental effects, but are always evidently adapted to one end, *viz.* the equilibrium of the body. This accounts for the serpentine shape of a well-formed spine, which (viewed from behind) is always, 1. convex from the os coccyx to the junction of the os sacrum with the ilia; then 2dly, concave from that part of the sacrum upwards to near the true ribs;

thrown considerably more forward than in the movement last described, and the line of gravitation falls so much beyond the supporting foot, that an immediate fall would ensue but for the rapid approach of the suspended limb ;* which no sooner reaches the ground, than a similar aid is again required from its fellow. To walk or to

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then, 3dly, convex as far as the neck ; then, 4thly, concave again till it reach the atlas. The first of these spinal curves (that of the sacrum) is caused by the spinal column pressing upon the upper extremity of the sacrum, and at its other extremity by the force of the gluteus magnus, while its middle part receives a rounded shape from the resistance of the ilia. The second curve is caused by the sacro lumbales and longissimi dorsi constantly employed in raising the trunk from the horizontal to the erect position, as well as in preventing the centre of gravity from getting too forward. The third curve (that of the thorax) is caused by the pressure of the head and shoulders, and the necessity for throwing them back to sustain the centre of gravity which lies in front of the centre of motion. Lastly, the curve of the neck is caused by its dorsal muscles, which are more numerous and more powerful than those in front. Had the spine been straight, the centre of gravity would, of necessity, have been so restricted in its range backward or forward, that the man could not with steadiness have supported the trunk of his body on its sacral extremities, during the extension of the hip and the knee-joints. It is the duty of the latter and of the joint at the ankle to cooperate with the curvatures of the vertebral column. And like those curvatures the joints in question are alternately concave and convex. Thus an extensive range of movement is obtained, and a greater facility in balancing. Just as in the case of a rope-dancer, who walks a rope with greater or less ease according to the length of the pole.

In the vertebral column of quadrupeds or of birds, nothing is to be found bearing resemblance to the three first named of these curvatures, that occupy in the human spine, the sacral, lumbar, and thoracic regions. Since animals seldom assume the erect posture, their more usual centres of gravity and centres of motion are not situated as in the human subject. Hence, in quadrupeds, that remarkable difference in the spinous processes of their movable vertebræ. In Man these processes all incline towards the sacrum. They are drawn towards one particular point while the body passes from a horizontal to an erect position, or they are balanced upon that point by the muscular force of the upright figure. Towards that point accordingly, the first of the spinous processes of the sacrum is sometimes directed upward. In quadrupeds a different appearance of the spinous processes arises from the same cause. They are inclined regularly (both the dorsal and lumbar) to a point near the middle of the spine—a point forming the common centre of motion between the two extremities of the trunk, that are alternately raised and depressed in progressive motion. The muscles chiefly employed in producing these inclinations are the latissimi, and the longissimi dorsi, the sacrolumbales, the semispinales, and the multifidi spinæ. The three first draw the spinous processes upward, or towards the head of the animal ; the two last draw them downward, or towards its sacrum.

* On the motion of quadrupeds we translate as follows from Borelli, pars 1ma. *de incessu Quadrupedum*, cap. 20. prop. 165. A notion, he observes, has prevailed, that animals move forward two feet alternately while the other two remain at rest, in a way resembling the walk of bipeds ; who support themselves on one limb during the advancement of the other. Taking this for granted, the Ancients have told us, that quadrupeds, in standing, make on a plane surface the quadrilateral figure A B C D. (Plate vi. fig. 5.) They might see that in a gallop, (plate vi. fig. 4,) the fore feet, A B, are lifted together, and together moved forwards, while at the same time both the hinder feet, C D, rest upon the ground E F. The feet A B next reach the ground, when instantly afterwards the hinder legs C D, are lifted in their turn, and together moved forward towards A B. And in this manner the quadrilateral figure A B C D, by its successive contractions and dilatations, performs what in horses and dogs we term running.

In the action of *walking*, however, or *going at a foot's* pace, it is evident that neither the two anterior limbs nor the two posterior are lifted and advanced at the same moment. They are moved alternately. When A, for example, is advanced, B is quiescent, and *vice versâ*, when B is put forward, A rests on the ground and supports the body. But it is not equally easy to distinguish what may be the order of movement generally, and what relation the motions of the hinder and of the anterior limbs bear to one another ; whether, for example, the two near feet A and D move together, or whether A moves at the same time with C. The rapidity of the movement in Nature, would make this a matter difficult of decision. Philosophers, accordingly, prepared themselves to solve the question by reasoning as follows. If the two feet A and D (on the near side) should be raised together and lifted forward at the same time, the animal would tumble and come to the ground on that near side. Therefore, say they, it must stand to reason that the off fore foot B (*dexter anticus*) must be lifted and advanced together with the near hind foot D, (fig. 5,) that so those feet of the animal which are diametrically opposed may at the same moment be together in a state of rest or together in a state of motion.

I am surprised, continues this learned Naturalist, that the difficulty and absurdity which such a movement involves, have escaped observation. They grant that an animal in motion must be steadily balanced lest it should stagger or fall. And this is given as a reason why the animal cannot move at the same time the feet A and D on the same side ; because in case of such a movement the centre of gravity of the oblong body, and consequently its line of gravitation, would be perpendicularly either over the right line B C, where the two off feet form the support of the body, or on one side of it as towards A D, in which latter circumstance the animal would come down on that side. But let it be considered that when, at the same time, the two feet B and D, diametrically opposed, are lifted and propelled, the whole incumbent weight of the animal must still rest upon the two feet planted on the ground ; in which case the line of gravitation will fall perpendicularly, not over a wide space, (*spatium amplum*,) but over the line A C. The animal will therefore stagger and vacillate as much here as in the circumstances before dreaded, and its position be equally hazardous or unsteady. Next let us observe the arrangement of the feet after the first movement has been made : after, for example, the foot B has been transferred to K, and the foot D to S. The two near feet A and S become now contiguous ; while K and C on the off side are as remote from each other as possible, so that the four feet of the animal lie at the three angles of a triangle, of which the base K C is the longest side, and A B the shortest altitude. A position this far from any thing like firmness. And from this position, after moving the feet C and A and transplanting them to I and V, the animal would return to its original quadrangular station of safety I S V K, similar to A B C D. These alternate positions of safety and of peril would have been unworthy the wisdom of Nature in a case where it is easy to have avoided them.

The author then, in the proposition next following, explains thus the mode by which progression takes place in quadrupeds. Let the oblong frame of the body of a horse, (plate vi. fig. 6,) supported on its four fulcra or legs, (which rest, like four columns, on A, B, C, and D, their points of contact with the ground,) be understood to cover the four angles of a quadrilateral figure or rectangle. The line of gravitation will fall perpendicularly upon E, near the centre of the quadrangle. This position of the animal will, consequently, be the firmest possible.

The movement forwards commences from one of the hinder feet, suppose C ; which is, in this example, the near hind foot, and which by a back-stroke, or powerful pressure backwards against the ground, advances forcibly the line of gravitation from E to G. This done, the foot B is suddenly lifted and transferred onward as far as H. This transposition is easily made, because the line of gravitation in the first instance falls within the triangle A B D, and in the second it falls within the trapezium A B F D. In the former case it is supported by three, and in the latter by four columns. While now the three feet A D F remain planted firmly on the ground, comprehending within their three points of contact upon it the extremity G of the line of gravitation, the near fore foot B (*anterior pes sinister*) is next planted on H, and the line of gravitation, by the continuance of the impetus before received, is now transferred to I, namely, to the centre of the rhombus A H F D. Thus is completed the progressive impulse on the near side by means of the two near legs ; and no sooner is it completed than D, the off hind foot, gives in its turn a push or back-stroke to the ground, and advances, as well as the off fore foot A, to take up a new position.

What we are here explaining, continues Borelli, in animals, is not a movement of all their parts at once urged forward with an equal velocity, and in one and the same direction, as happens in the act of flying, of jumping, or of vermicular progression, (*reptatio*,) but is rather a movement resulting from the transfer of the weight of certain parts, while supported upon other parts which remain at rest, so that the *progressing* animal may be said to advance while *standing*,(*stans—progreditur*.) This continued support, and this transfer of its weight in the progression of the animal should be liable to no shiftings or risk of injury, but should be firm and steadfast ; effected by a sufficient muscular power ; and by no more than is sufficient, *i. e.* by the least possible labour. But in order that every risk of falling may be provided against, there is a necessity that the number of props or sup-stand against a high wind requires the same sort of inclination of the upper portion of the body.*

(273.) 6. Dancing and leaping. A hop differs little from a leap, except in being performed on one foot. In both actions the body is inclined forwards or sideways, according to the distance as well as according to the direction of the proposed saltus or saltatio. The greater that proposed distance,* the greater will be the inflection of the pelvic extremities. In both cases also there is an inflection of the ankle, knee, and hip joints previous to the sudden extension of them which causes the spring from off the ground.†

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porting columns should be more than two; and should consist of four, or at least of three, within which the line of gravitation (drawn perpendicularly from the centre of gravity in the body of the animal) must be included. All these important purposes are answered in the mode of progression above detailed. Moreover the movement of the entire animal frame is easily accomplished in the manner stated; because its entire weight has no need of being held suspended or lifted from the ground. The only weight requiring suspension is that of the one limb to be moved and advanced. First of all the centre of gravity is shifted forward by an impulse proceeding from the hind foot; an impulse not attempted by either of the two fore feet, because pressure from either of these upon the ground in front would drive the centre of gravity backward instead of anteriorly; but such an impulse as has been described proceeding from an elongation of the hind leg, acting like a pole in the hands of a waterman. The whole animal frame through this contrivance is impelled forward by the inflection of three upright columns; just as any vehicle is propelled by the wheels which support it. Again, observe, that in the suspension of the hinder foot through the action of the flexor muscles on the joints required; and afterwards in the advancement, on the same side of the animal, of its fore foot; the advantages of facility and speed must make the necessity of such a mode of operation quite apparent.

We need only remark on the foregoing statement of this acute Philosopher, that the truth of his system is very plainly distinguishable in the *walk* of a horse, but that if Borelli ever rode out with his patroness, Christina of Sweden, and that they put their horses to a *trot*, he must have observed the near foot C (plate vi. fig. 6) of her Majesty's courser, on striking the ground, so *immediately followed* by the stroke of the off hind foot D, as to give the appearance of a simultaneous impulse. And there can be no doubt that in a quick movement, the limb D is on its way to take up a new position before the limb B has reached the ground at H. Consequently in representing rapid progression, the feet diagonally opposed may be shown raised off the ground together; although the foremost of them must, according to Borelli, be always nearest the ground so as to strike it first. This position of the quadruped balanced upon two legs is undoubtedly unsteady, and would never take place in progressing slowly, as in walking. But during a brisk trot the suspended limbs (one on the near, the other on the off side) act as librators, and form an equipoise to each other, which is so momentary as never to be hazardous as long as the muscles play freely. Borelli admits that the muscles in brisk action have greater facility of balancing than when comparatively quiescent. He remarks in another place, that when dogs attempt to stand on their hind toes, (see plate vi. fig. 8,) or horses on their hind hoofs, they speedily come to the ground, having no power of remaining steady in an erect position; but they have power of walking in that erect manner, because in the course of locomotion they may balance *a vacillation towards one side by an opposite leaning towards the other:* just as boys go about, and even run, supported by stilts, but cannot remain quiescent without tumbling immediately. Book i. p. 173. Horses are sometimes trained (by tying their near or their off legs together) to practise a kind of ambling trot. This is an easy pace for the rider, but is not natural to the animal. Perhaps the steed of her Majesty of Sweden was so trained. It is remarkable that the plate in Borelli's Work represents the animal supported on *two* legs.

* In running, the lumbar vertebræ are placed as in stooping; the whole spine makes an angle with the sacropubic line; (Art. 248;) the recti cruris, the psoæ, and the iliaci draw the trunk forward and incline it to the pelvis. The femur is, at the same time, inflected by the psoæ and iliaci; the tibia by the semitendinosus, semimembranosus, and biceps; also the foot and its phalanges are inflected and make angles with the metatarsal bones by the action of the tibialis anticus, by that of the extensors (great and small) of the toes, and by that of the extensor of the great toe. This bending of the phalanges is indispensable to running, as also the inclination of the trunk, which inclination, in a walk, varies from a stoop to the upright posture, but in running is continual. Remark also that the centre of gravity never rests during the race for an instant, but bounds forward in alternate undulations from side to side, varying its situation according to the balance of the figure by its thoracic extremities. Observe as the right foot strikes the ground the right shoulder lowered, the right arm advanced and its fore arm inflected; the left shoulder raised, the left arm thrown back, and its fore arm extended. Reverse these positions when the left foot strikes the ground.

* The elasticity of the cartilaginous part of the limbs is called forth in dancing and leaping as in running, and distinguishes all these movements from the more deliberate process of walking. The centre of gravity in those more lively movements is no longer quietly and insensibly transferred from the right to the left side, or *vice versa*; but is thrown off as by the action of a spring, with a jerklike impetus, which, in the trot of quadrupeds, is very perceivable. The fore foot in trotting reaches the ground with such force as excites reaction, and for a time suspends the forward movement; until the back-stroke from the hind leg diagonally opposite takes effect, and again with a sharp jerk propels the centre of gravity. The same observation applies to the gallop, during which the spring-like reaction is caused by both fore legs instead of one, and counteracted by the propelling impulse of both the hinder limbs.

The tiptoe position in dancing is the work of the extensors, (Art. 256,) together with the tibialis anticus, (*ib.*) while the peronæus (*ib.*) turns out the toes and points them. Dancing requires the simultaneous exertion of a great number of muscles. Those of the trunk and superior extremities are employed in balancing the figure and keeping it erect; those of the leg and inferior extremities are chiefly employed in various modifications of the several motions that have been particularized. (Art. 254, 255, 256.)

In leaping, the impetus, says Da Vinci, (cap. 260.) is accompanied by a rapid extension of the body immediately after having been bent, like a spring, at the joints of the hip, knees, and ankles. During this extension the body describes an oblique line. It is carried by one force upwards and by another forwards; between which two forces it moves in the curve of a large arch, such as may be seen described by the feet of the person leaping. "In preparing to take the spring, the body and thighs are drawn together. The muscles of the leg draw up the heel, so that the figure rests on the ball of the foot. The arms are thrown back. They assist, like wings, in the impulse. When the figure alights, the arms are raised above the head, and the centre of gravity" (line of gravitation) "is near the heels." Flaxman, p. 128. For accomplishing the motions above-named, we observe that the solæus, the tibialis anticus and posticus, and the peronæi, (Art. 256,) are first employed to tighten the sole of the foot. The extensors elevate at the same time the phalanges digitorum pedis. (*Ib.*) Then follows a strong propelling impulse to the body from the two first-named of these muscles. And last of all, a sudden contraction of the crursei, or crurales, (Art. 255, note,) impels the femur upwards; and a similar contraction of the glutæi, the semitendinosi, and the bicipites (Art. 254) gives a similar upward spring to the pelvis.

† We translate as follows from Borelli, pars 1ma. *de Saltu*, prop. 172 and 173. Let A B C (plate iv. fig. 7) represent a bended bow placed in an erect position round the joint (*nodus*) B, and resting upon the ground at C. Let F E be its line of gravitation, and let it be suddenly widened by the contraction of the cord G Q H placed at its outside edge. The result will be to make the bow spring from the ground. The bow accordingly, and its centre of gravity, will by that impetus be transplanted from the ground towards F. (Compare note to Art. 270.) This movement is no other than that of leaping, to illustrate which in the human figure we have but to add two other bows, H V X and N D E, acting simultaneously and conjointly with A B C, and place the extremity of the lowest bow on the ground at E. A B will represent the spine; B V the line of the femora; V D of the legs; and D E of the feet. Let, next, A B E (plate iv. fig. 6) represent the frame of the human body standing as at No. 1, in an erect posture, *viz.* with the bones of the legs, femora, and spine extended (as nearly as may be) in a right line; as so many pillars one above the other, resting perpendicularly on the ground R S. The common centre of gravity G will in this case be distant from the ground the length of the lower extremities. Next let the posture be changed for that represented in No. 2, where the several joints at B, C, and D are bent so as to make acute angles. By this inflection the distance G E of the centre of gravity from the ground is lessened by about the length of a leg; or by only one half of its former distance while the man stood erect. If during this position a contraction be suddenly and forcibly made (at one and the same instant) of the glutæi, the vasti, and solæi muscles, the result will be

(274.) 7. Climbing. This attitude includes both the methods stated in Art. 267, for supporting the centre of gravity. The superior extremities are employed in suspending the body; the inferior, in their ordinary capacity of fulcra, or sustaining props, beneath it. The chief consideration for the artist is to give (as in the recumbent posture, Art. 269) neither more nor less action to the muscles of any limb than is necessary for the work it has to do, but to divide the weight naturally and suitably between the several suspending or sustaining limbs.

8. Pulling downwards, upwards, or horizontally. In these movements, wherever great strength is required, the arms are assisted by the weight of the body. If the pull is downwards the action resembles that of climbing, and the body is placed as nearly under the object pulled as is practicable. If the pull is made either upwards or horizontally, the feet are if possible so planted as that the object pulled might be seen by the figure himself between them. The horizontal direction, however, does not always afford to the feet a station so advantageous. They are therefore brought forward as nearly in the direction of the object as the nature of the ground permits.[*]

9. Pushing in three similar directions. The available muscular force for these motions being upon the whole weaker than for those last mentioned, greater effort must be exhibited for pushing any object than there would be for pulling one of the same weight.

(275.) 10. Carrying any weight. "The centre of gravity," observes Flaxman, "is the centre of the incumbent weight falling between the feet, if supported by both, or on the supporting foot." By the "incumbent weight" must be understood the weight of the body of the carrier joined to that of the burden. It is, says Da Vinci, necessary to equilibrium that so much of the weight of the carrier's body be thrown on the side opposite to that which bears the burden as may amount to a counterpoise; consequently the line of direction or gravitation will not fall from a point in the centre of the burden, unless the latter be considerable.[†]

11. Throwing any weight, or striking. To either of these operations the lower limbs are often as essential as the upper. The right hand is generally most employed; and, in the case of striking or of throwing any thing in a forward direction is powerfully assisted by the left leg and foot, which must be advanced in the direction of the blow.[‡] If, however, the blow be given backwards, the longer sweep may be obtained for the right arm by advancing the right foot. A blow forwards with the left hand requires, for the same reason, the advancement of the right foot.

12. Falling. In order to represent a falling figure, and without any part at rest, let that portion of it which is heaviest be seen to sink most, or be on its way to be lowest. The appearance of any figure previous to a fall may be easily given by transgression of any of the above rules of libration.[*]

We have now bestowed upon the details of Outline so much of our allotted space, as leaves us incapable of touching otherwise than briefly on the divisions that remain of the subject. But we have not limits for a perfect Treatise; and we prefer being, if possible, practically serviceable on one or two essential points, to the likelihood of being superficial upon all.[†]

Composition so defined as to include the contrivance as well as the performance of a work.

(276.) Composition is that exercise of the Art which *puts together*[‡] the materials of which we have hitherto been examining some individual elements. To composition belongs not only the grouping and judicious arrangement of outlines, but also the use of that relief and force, and increased power of expression derived to outline from the aids of chiaroscuro and colouring. Under this one general term, *Composition*, we would include all that relates to the formation or execution of a picture; from its earliest existence in the fancy of its author to its perfect completion upon his canvass;[§] all that can

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that the three *bows* A B C, B C D, and C D E will expand with great force. Through the reaction of the ground, the centre G of gravity will be impelled upwards to F. And because this movement is the consequence of an impetus, which acting uniformly in one direction cannot cease of itself; therefore it will of necessity raise the weight of the man's body clear of contact with the ground, and carry it upwards with a spring through a certain space, until the gradually increasing power of gravity equals the projectile power. From what has been said above, it is plain that three bows in the human subject are in constant exercise. They are not put into action through their natural hardness or elasticity, (*materiali duritia et tensione*,) but by the voluntary action of the extensor muscles.

[*] Da Vinci, *della Pittura*, cap. 234, 235.

[†] *Ibid.* cap. 200. 206, 207. 263. 350.

[‡] *Ibid.* 261, 262. It is justly remarked of that admirable figure called the Fighting Gladiator, or Lesser Ajax, that the right hand could not strike a blow while the right leg is in the position represented by the sculptor. The left arm, on the contrary, if a shield were upon it, is admirably placed for warding off a stroke, and for protecting any supposed object beneath it.

[*] A flying figure is opposed to the foregoing. It has no apparent support, yet the heaviest part of it must be represented rising or mounting upwards. The frescos of the Italian fathers of Painting exhibit examples, never to be surpassed, of the flying figure.

[†] "The port-crayon," observes Sir Joshua Reynolds, addressing himself to the students of 1769, "ought to be for ever in your hands. Various methods will occur to you by which facility of drawing may be acquired. I would particularly recommend that after your return from the academy, (where I suppose your attendance to be constant,) you would endeavour to draw the figure by memory. I will even venture to add, that by perseverance in this custom, you will be able to draw the human figure tolerably correct, with as little effort of the mind as is required to trace with a pen the letters of the alphabet." Reynolds, *Works*, (Malone's 8vo. edition,) vol. i. p. 40.

[‡] See our Lexicon for the words COMPONE and COMPOSE. Also Johnson's *Dictionary*, folio edition, for the fifth meaning of the word *composition*.

[§] Bardon, in his vocabulary prefixed to his *Histoire Universel relatif aux Arts*, 8vo. 1765, thus defines invention: *Qualité dépendante du génie. Elle trouve les choses que la composition arrange.* Du Fresnoy also considers invention separately from composition, and calls it the first part of Painting. *Picturæ prima pars inventio.* See Reynolds, *Works*, vol. iii. p. 35. Dryden in his parallel, in the same volume, p. 256, between Poetry and Painting, says, invention is the first part of, and absolutely necessary to them both. Yet no rule ever was or can be given how to compass it. A happy genius is the gift of Nature. How to improve it many books can teach us; how to obtain it, none. That nothing can be done without it all agree. *Tu nihil invitâ dices faciesve Minervâ.* Without invention a Painter is but a copier, and a Poet but a plagiary of others. Under this head of invention, he adds, is placed the disposition of the work to put all things in a beautiful order and harmony, that the whole may be of a piece. The composition of the Painter should be conformable to the text of ancient authors, and to the custom of the times. And this is exactly the same in Poetry. As in the composition of a picture (p. 258) the Painter is to take care that nothing enter into it which is not proper or convenient to the subject, so, likewise, is the Poet to reject all incidents which are foreign to his Poem. Sir Joshua Reynolds, at p. 107, gives a more practical definition. The invention of a Painter, he says, "consists not in inventing the subject, but in a capacity of forming in his imagination the subject in a manner best accommodated to his Art, though wholly borrowed from Poets, Historians, or popular tradition. For this purpose he has full as much to do, and perhaps more, than if the very story was invented: for he is bound to follow the ideas which he has received, and to translate them (if I may use the expression) into another Art. In this translation the Painter's employ his powers of invention and imitation, whether upon combinations selected from a well-stored mind, or upon objects as presented immediately to his eye. This extended view of composition in Painting combines a consideration of the influence it is designed to have on the spectator, with the various operations of the Painter's own head and hand for this purpose.* We confine ourselves at the same time to—

Of Composition.

I. The representative powers and moral purposes of the Art.

II. The objects to be represented.

III. The means, rules, or modes of representation.

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invention lies; he must, in a manner, recast the whole, and model it in his own imagination. To make it a Painter's nourishment, it must pass through a Painter's mind. Having received an idea of the pathetic and grand in *intellect;* he has next to consider how to make it correspond with what is touching and awful to the *eye*, which is a business by itself. But here begins, what in the language of Painters, is called Invention, which includes not only the composition, or the putting the whole together, and the disposition of every individual part; but likewise the management of the background, the effect of light and shadow, and the attitude of every figure or animal that is introduced or makes a part of the work." Fuseli, in his third Lecture, p. 110, adverts to a question whether it be within the artist's province or not to find or to combine a subject from himself, without having recourse to tradition or the stores of History and Poetry. Why not, he exclaims, if the subject be within the limits of Art and the combinations of Nature; though it should have escaped observation? In his fifth Lecture he calls composition, in its stricter sense, *the dresser of invention:* and observes that composition superintends the disposition of the invented materials. Opie, in p. 65 of his Lectures, the successor of Fuseli, thus expresses himself on the same subject. Invention as a general power depends on the command of a large fund of ideas, and an intuitive readiness of associating and combining them in every way possible. As a technical power, invention consists not in composing in the first instance the story to be represented, but in seizing at once on the peculiar and prominent feature of the subject; placing it in the noblest and most interesting point of view; taking in all that belongs to the time and place chosen; discriminating the characters; entering into their situation, circumstances, and relations; and all this with a reference at the same time to the genius and powers of the Art by which they are to be embodied. The author of the *Elements of Art*, p. 206, has a note to the following effect: "The conception of a subject, story, or plot; the discovery and connection of such events and circumstances as are best calculated to convey whatever moral the Poet and the Painter design to express, must be considered the first and highest effort of invention. From this point the Painter and the Poet start in different directions; each to run his particular career. The subject as conceived in the Painter's mind must now be transferred to the material upon which he works, and such an arrangement made of the figures and objects connected with it, as may be most judiciously adapted to strike the eye and the mind of the beholder. This second operation is called disposition or composition."

The reader who examines and compares together the foregoing eminent authorities, cannot but be struck with the similitude between the definitions of invention and of composition. He will see that the invention of a picture is no other than the composition of it in the mind before being transmitted to the canvass; and that what is termed by some the composition of a picture, is in fact that very same invention or mental composition exhibited afterwards to the eye under appropriate forms and colours. By making, therefore, composition the generic term, and including under it the two processes; first, of the Painter's mind, and secondly, of his pencil; processes which, distinct as they are, ought never to be separated, may we not simplify to the student what seems to have admitted of occasional mystification? There does not appear much difficulty in comprehending that a selection being first made of such particulars as are proper to be represented by the Art, is next to be followed by a selection of suitable materials and modes of representation.

* Every Art that addresses itself to the imagination necessarily involves three considerations. 1. Susceptibility of the artist to receive from Nature and from education impressions of beauty and sublimity. 2. Susceptibility of the spectator, reader, or auditor to comprehend and sympathize with the artist. 3. Skill in the artist in the selection and use of materials for exciting that susceptibility of the spectator, reader, or auditor. In some Arts, as in Music, or in Dramatic Poetry, a fourth consideration is important to success, namely; 4. Skill in the performer to comprehend and execute the work of his composer. Other Arts, as Painting, Sculpture, Architecture, &c., most generally unite the offices of composer and performer in one and the same individual. Applying, then, the three first-named particulars to the theory and practice of Painting; we observe,

1. Respecting the susceptibilities requisite for the student, he must to succeed in this arduous profession answer to a description given in the Lectures of a late celebrated professor. "He must not be one who has mistaken a pretty kind of imitative monkey-talent for genius; one who has taken up the Art to get rid of what he thinks a more vulgar or disagreeable occupation—or merely on the supposition of finding an easy amusement: but he must be such a one as is impelled by no consideration but a real unconquerable passion for excellence; one who undismayed looks all difficulties in the face; to whom obstacles are a stimulus; who receives fire from what quenches others—one in short, who is prepared to sacrifice time, ease, pleasure, and profit, and devote his entire self to the Art." (Opie, *Lectures*, p. 20, 21.)

We may further remark that to the imagination of a Poet, the Painter of History must unite a peculiar talent for dramatic or scenic effect; a nice perception and ready invention for such incidents as are termed "By-play" in the phraseology of the stage. For the Painter is to do with his colours what the actor must perpetually do with his person, namely, express by actions, looks, and gesture alone the sense, design, and spirit of his author. Where an incident is discovered in which at one and the same instant a number of very significant actions, or else one simple burst of expression can be produced to explain, at a glance, the story: such an incident may form a proper subject for Painting or Sculpture. In our allusion, however, to scenic talent, we mean a much higher degree of it than perhaps theatrical representation often admits of. Sir Joshua Reynolds (*Works*, vol. ii. p. 133) observes upon "the necessity," in theatrical performances, "that every thing should be raised and enlarged beyond its natural state; that the full effect may come home to the spectator, which otherwise would be lost in the comparatively extensive space of the theatre. Hence the deliberate and stately step, the studied grace of action, which seems to enlarge the dimensions of the actor, and alone to fill the stage. All this, though right and proper in its place, would appear affected and ridiculous in a private room, (*quid enim deformius quam scenam in vitam transferre.*) We have no idea of recommending theatrical subjects for the student in Historical Painting. On the contrary, we join heartily in the opinion of the lively author of *Elements of Art*, where he remarks, that the "taste of the historical artist too often receives a bias which materially affects the conduct and character of his work. He finds it impossible to get out of the theatre, he cannot separate in his imagination the natural situation from the dramatic exhibition, nor extricate his pencil from those accessories of scenic extravagance, which, mingling with all his conceptions, pervert the purity of his Art, and destroy the simplicity of Nature." In the same note, the author, alluding to the French School, describes the Gallican critics as having "lost all relish for the plainer fare of Painting; and once accustomed to theatrical luxuries, as beginning to think the unostentatious dignity of Raffaelle and the Roman School, tame and inspid." (p. 309. 311.)

2. The next consideration is, how far spectators possess the faculty of entering into the meaning of the artist, and of sympathizing with the emotions he expresses. This is a most important circumstance to every aspirant for pictorial fame. He cannot, he ought not to be deaf to praise from his contemporaries. To be admired he must choose popular subjects. Yet how often may he monopolize admiration by committing, in contradiction perhaps to his own judgment, enormous outrages upon truth and Nature! In this dilemma he must frequently tax his ingenuity to the utmost, and must select the least absurd among popular absurdities. He must endeavour to put himself in the situation of the most judicious among his judges. He is like a writer, who, for the approbation of judicious readers, is expected at all events to write common sense, and to use language that is intelligible; but yet that his readers may be kept awake, he must not fail to interest as well as to convince them, to arrest their imaginations as well as lead their judgment, and to appeal effectually to their sensibility.

3. With regard to the materials for exciting the susceptibility of a spectator, it is proper here to repeat a remark made by the best writers on Art, that, for the purposes of Painting, a sufficient degree of verisimilitude in any picture, is to be obtained rather by faithful adherence to the general character of objects, than by excessive attention to details. We therefore scarcely need to say, that in using the terms "Truth" and "Nature" as applied to Painting, we

“ Of these three divisions, the first relates chiefly to the attractions of Painting for the eye or mind of the spectator; the other two to the labours and the judgment of the artist. The second regards more especially his choice of materials drawn from observation of Nature: and the third is connected principally with such methods of pictorial arrangement as result from exploring with critical industry the works of other hands, and combining their experience with his own.

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(277.) i. The first of these particulars demands careful attention and investigation from every composer in this, or indeed in any Art. We have here only room for a brief caution to every aspirant after mastery in pictorial composition to avoid attempting more than the limits of Painting are competent to attain. If his ultimate ambition be to instruct, to attract, and to amuse, he must aim first of all to be intelligible. In his choice of a subject, as well as in his treatment of it, he must address himself to the prepossessions, to the habits and mind of his spectator.* Whoever would obtain the power of impressing his contemporaries will not employ obsolete terms; will not adapt the language

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do not mean such an imitation as merely serves to deceive the beholder into a belief that it is no imitation. Nobody in his senses ever expects a picture to be the thing which it cannot be, the thing represented. This would be like believing Kemble to be the real Coriolanus! Such a transubstantiation would remove all the pleasure which the mind receives from tracing a resemblance, and from pursuing the infinitely varied associations which that resemblance calls up. But by attention to Truth and Nature, we mean absence of affectation and excess, as well in colouring as in drawing, and an accurate observance of those delicate gradations which the tints and forms and shadows of Nature universally unfold. In a word, we mean a chaste and scrupulous adherence to the “ modesty of Nature.”

* “ Every Art,” says Sir Joshua Reynolds, “ like our own, (vol. i. p. 225.) has *fluctuating* as well as *fixed* principles. An attentive inquiry into the difference between them enables us to determine how far we are influenced by custom and habit, and what is fixed in the nature of things. To distinguish how much has solid foundation we may have recourse to the same proof by which some hold that wit ought to be tried—whether it preserves itself when translated. The wit is false which can subsist only in one language: and the picture which pleases only one age or nation, owes its reception to some local or accidental association of ideas.”

Agreeably to this doctrine it will be proper for every artist to make himself acquainted with the nature and origin of those conventional licenses which have been transmitted from one Age to another, and how many of them retain their hold upon his patrons and admirers. In any Art which, for the amusement, or, as it may be, instruction of mankind, practises upon their imaginations, it must be always important to ascertain, how far the parties to be amused will consent to enter into the delusion; how much of the improbable, or of the marvellous they only tolerate, and how much they eagerly expect. Something more, it is evident, must be granted to the contriver of a work of Art, besides our good-natured supposition, that the object contrived represents a real existence. We must be prepared to grant likewise, that the object is employed in some act, or occupies some situation which we consider, or have been taught to consider suitable to its character. Shakspeare's Witches were, in Shakspeare's time, considered as the representation of a sort of beings actually existing. But the master pencil of that great observer of Nature was careful to represent them conformably to the prevailing notion of the fantastic pursuits in which those formidable personages were said and were believed by the nurses in the time of James I., and doubtless by King Jamie himself, to employ themselves. The nurseries of the XIXth century seem to be losing, one by one, the venerable hobgoblins which supplied such fruitful materials for the sublime and the terrific to the imagination of our forefathers.

Great licenses were permitted to the early schools, and have been continued more or less to their succeeding followers. But that these liberties are becoming less and less endurable in the progress of modern society may be fairly augured from some extracts which we quote from vol. iii. p. 564 of the *Manchester Transactions.* Quotations from the same paper have been dispersed in almost every periodical notice of the Arts, since its publication, and may be said to have “ gone the round” of the Encyclopædias. We are inclined to an opinion that many of the absurd licenses there exposed arose not merely from literary or scientific deficiency, and from a want of greater refinement in manners, but also not unfrequently from the barbarous taste of patrons who accepted flattery at the risk of perpetuating absurdity. The paper in question comments with some severity upon Raffaelle in his Cartoons, “ introducing monks and Swiss guards; putting into a boat more figures than it is evident the boat could contain;” making “ Pope Julius II. present at the chastisement of Heliodorus,” recorded in the third chapter of the second book of *Maccabees;* introducing Venetian senators while Pope Alexander excommunicates Barbarossa; and bringing together in the School of Athens, Aristotle, Plato, Dante, and Petrarch. “ In like manner,” continues the writer, “ when the same great master paints the dreams of Joseph and his fellow-prisoner over their heads; when similar contrivances are used by Albani, Parmeggiano, and Fuseli; is it not evident that real and feigned existences are unnaturally introduced in one narration? When Polydore chooses to represent the death of Cato, and exposes the hero of the piece with his bowels gushing out; when Paul Veronese, at a banquet, painted with his usual magnificence, places before us a dog gnawing a bone, &c.; when the same first-rate artist introduces Benedictine monks at the marriage of Cana; and, in a picture of the Crucifixion, puts Roman soldiers in the jerkins of the XVIth century, and adorns their heads with turbans; when Guido, in a Painting of Jesus appearing to his Mother, places St. Charles Borromée in a kind of desk in the back-ground as witness to the interview; when Tintoret, at the miraculous fall of manna, arms the Israelites with fusils; and Correggio appoints St. Jerome as the instructor of the child Jesus, common sense revolts at the impropriety, and exclaims, *Quicquid ostendis mihi sic, incredulus odi.* The mythological taste of the learned Poussin is well known; but Rubens seems to claim the merit of having presented to the world a still greater number of supreme absurdities in this learned style; nor is it easy to conceive a more heterogeneous mixture of circumstances, real and imaginary, sacred and profane, than the Luxembourg Gallery and the other works of that great master perpetually exhibit.” The writer next proceeds, without any respect for national prejudices, to criminate Sir Joshua Reynolds: but we forbear; and only remark, that we might quote also foreign authors on Art, to prove a similar strain of criticism to be gaining prevalence among our continental neighbours.

Raffaello, says Milizia, (in his *Dizionario delle Belle Arti*, vol. i. p. 219.) *e mirabile nell' espressione d'ogni suo assunto, di ciascuna figura, di ciascun accessorio. Ma con que' suoi Giuli II. e Leoni X. fatti intervenire dove non potevan essere, ha egli conservata la convenienza?* See also the works of Chevreau for other examples.

These therefore are licenses which, at the present day, would be abandoned; notwithstanding the high and, in most respects, excellent authority of Sir J. Reynolds, “ one is,” says he, “ so much used to anachronism in church pictures, that it ceases to be an object of criticism,” vol. ii. p. 314.

Neither does Sir Joshua's defence of Allegorical Painting (vol. i. p. 214.) seem likely to preserve this style of Art from decline. “ If Allegorical Painting,” he observes, “ produces a greater variety of ideal beauty, a richer, a more various and delightful composition, and gives to the artist a greater opportunity of exhibiting his skill; all the interest he wishes for is accomplished. Such a picture not only attracts but fixes the attention.” But what if Allegory belongs more to the *fluctuating* than to the *fixed* principles of the Art—to borrow again Sir Joshua's words as quoted at the commencement of this note? What if the public taste, we mean the taste of well-educated multitudes, either rejects or only tolerates Allegory? A Poet does not compose only for Poets, nor a Painter paint only for Painters. Let us hear, however, the judicious advice of one of Sir Joshua's successors on this subject. “ Man and Nature,” he observes, “ are the great objects of the Painter; and though he is competent to ascend with the Poet to the wildest regions of fancy, and people with a new creation an imaginary world, yet human events and human passions furnish him with the materials most congenial with the powers of his Art, as well as most conducive to those moral effects which it is so admirably calculated to produce.” (*Elements of Art*, p. 358.) Hayley has not unhappily termed those pictures in which Allegory is employed “ painted riddles.” This, observes the writer just quoted, seems a condemnation too unqualified. Allegory, like all the other instruments of Painting and Poetry, may be injudiciously managed; but in skilful hands it is capable of being made an ingenious and efficient vehicle of refined sentiment and moral truth. The Painter, however, should *be cautious in the use of it.* An Allegory which does not explain itself to

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Of Com
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of his Art to superstitions long ago forgotten or exploded, or to a state of society in other times* entirely different from his own.

Again, in another respect, some control over the flights of the pencil is necessary. There may be sometimes danger of attempting to invade the province of other Arts. No attempt can be more fatal to the invader. The province of this Art, rich and ample, and beautiful as it is, has its boundaries. An historian or biographer, or chronicler of legends, or novelist, of epic poet, can describe to us a succession of events; a dramatist can put that succession of events before us in a sort of living picture on the stage. But the Painter has no such power.* His composition restrained to one point of time cannot prepare us by those previous details of character which give interest to the story. For these details he must be indebted to what passes in the minds of us spectators, either from our legendary knowledge of the subject painted, or from the course of our experience.†

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a spectator of ordinary discernment and information, is an enigma that conceals the truth which it was intended to display. The impression of the subject is weakened by the effort that is required to understand it: and he whose work must be accompanied by an explanatory dissertation may deserve the praise of learning and ingenuity, but he will neither command the attention, nor interest the feelings of the public.

An Allegorical Poem or Picture, ill contrived, is a maze of meaning in which we do not much like to wander, although we may be presented with the clue. But it is not enough that an Allegory be clear and expressive. It should be constructed also to dignify, enforce, and adorn whatever it is employed to display. In Art it must be picturesque as well as appropriate; graceful as well as just. (*Ibid.* p. 361.) The Allegorical Painter, therefore, will do well not to attempt flights in any track through which some popular Sculptor or Poet of well-established fame has not soared before him. Reynolds's "Tragic Muse" in the person of Mrs. Siddons, (of which picture there is a fine duplicate in the Dulwich Gallery,) as well as his "Garrick between Tragedy and Comedy," are exceptions. We may here add, that there is likewise in the Dulwich Collection another allegorical subject by Sir Joshua; namely, the "Mother and sick child," which we consider a failure. The idea seems suggested by the celebrated work of his contemporary, Roubiliac, in Westminster Abbey—the monument to Lady Nightingale. In Sir Joshua's adaptation of the idea, not only is the action of the guardian angel warding off the stroke of death vulgar, and bordering on the ludicrous; but the introduction of such machinery by superhuman agents into an affair of every-day life, destroys all their intended awfulness and grandeur. The mother and her child are, in expression and colour, touchingly beautiful. On the subject of this style of Art see Fuseli's fourth Lecture.

* It is matter of serious consideration with the artist of the present day how much more limited are his opportunities of interesting the public mind than were those of the gone-by giants of old. Architecture, not only in the temples of Greece, but in the churches and convents and palaces of Italy, was the foster-sister of Sculpture and Painting. Religion was their nursing mother. "To devotion," says Addison, (*Spectator*, No. 414,) "we are indebted for the noblest buildings in the world." He might have added, that the Arts of Poetry, Oratory, Sculpture, Music, and Painting, have likewise been indebted to the same all-inspiring influence. "It seems," says Professor Hey, (*Norrissian Lectures*, book iii. c. xv. § 10. 8vo. Cambridge, 1797,) "to be undeniably true that the Fine Arts are, generally speaking, infinitely more efficacious when exercised on religious subjects than on any others. The Paintings which have the greatest effect are on religious subjects." It must, however, be confessed that the absence both of enthusiasm and of superstition, which Christian civilization and the progress of rational piety must occasion, is not favourable to pictorial invention on religious subjects. If the robe of Popery has been termed affectedly gorgeous and theatrical, the mantle of Protestantism may be sometimes pronounced unnecessarily plain and in bad taste. A severe remark has been applied, and perhaps not unjustly, to several houses of prayer constructed in our own times, that they tend to remind us oftener of the preacher than of the Deity; oftener of the convenience of the lecture-room than of the immensity of the temple that "fills all space." The world perhaps is wiser, and casts away the toys of its youth. It appears, however, exceedingly probable that the more idolatrous, the more fabulous, the more legendary, were the popular religions of old, the more effectual would be their appeals to the imagination by means of Painting and Sculpture. The celebrity which those sculptured or painted works have now, is of a different kind from their original celebrity. *We* connect with an old picture the times and history of the Painter, and estimate it at a sort of antiquarian value. We amuse ourselves, not so much perhaps with its appropriateness to our own feelings, principles, and views of Nature, as with the effect which we fancy it must have had upon its first beholders. No new work of Art can expect this kind of celebrity. The living artist is limited to contemporary fame.

* By means of a series of pictures, all of them introducing the same hero in different circumstances, a *succession* of events may be said to be narrated by the Painter. Also, in a single picture, accessory particulars or episodes may be introduced, which lead the spectator either to foresee something that must follow the principal event; or to understand something that must have preceded it. It is remarked of Raffaelle, that the action of almost all his figures enables a spectator to conceive what they must have been doing the moment before, as well as what they are about to do. In his Cartoon of Ananias and Sapphira, the episode which introduces the latter in the back-ground counting the fatal purchase-money, is a kind of continuation to the story. According to the letter of the sacred history she did not come into St. Peter's presence until "about the space of three hours after" the death of her husband. But this is a very pardonable anachronism in such a Painting.

"Raffaelle," Sir J. Reynolds observes, (vol. i. p. 85.) "in representing the Apostles, has always given them as much dignity as the human figure is capable of receiving. No where is it shown that they had really such appearance. Of St. Paul in particular we are told by himself that his bodily presence was mean. Alexander the Great was low of stature; a Painter ought not so to represent him. This is taking an allowed license. A Painter of portraits retains the individual likeness; a Painter of history shows the man by showing his actions. A Painter must compensate the natural deficiencies of his Art. He has but one sentence to utter, but one moment to exhibit. He cannot, like the Poet or Historian, expatiate and impress the mind with great veneration for the character of the hero or saint he represents, though he (the narrator) lets us know at the same time that the saint was deformed, or the hero lame. The Painter cannot make his hero talk like a great man; he must make him look like one. Poetry speaks by raising our curiosity, engaging the mind by degrees to take an interest in the event, keeping that event suspended, and surprising us at last with an unexpected catastrophe. What is done by Painting must be done at one blow." p. 247.

† It is not enough for the artist to understand his own work himself. Out of his charming language of visible signs, he must use such as we spectators likewise understand. At our first glance he must, if possible, contrive to interest our feelings even without our being acquainted with the historical or fabulous incident which he commemorates. It must be some incident during which, in real life, though we were strangers to the parties concerned in it, we should desire to be ourselves actors, and should not be able to look on unconcerned. Suppose, for example, in the foreground the figure of a wounded wretch, stripped of his raiment, pale and emaciated through pain and loss of blood; and gazing with a look of despair upon a traveller in the distance, whom he seems to implore, with almost a last effort, for succour, but who is pursuing his way heedless of the sufferer. Suppose again, on the opposite side of the picture two travellers, unperceived by the wounded man, one of them looking without the smallest sympathy upon his distress, but passing hastily on, as if to escape his observation. Then imagine the other, the third traveller, who has just alighted from his horse, or from his camel, to be running up, with a countenance and gesture that bespeak unhesitating benevolence, to the assistance of the helpless person. Let an attendant who holds his beast cast a look of contempt upon the unfeeling passenger, and point at the same time to the afflicted object. We have here a scene perhaps sufficiently intelligible, and in which we should ourselves desire to be actors.

But besides intelligibility, there is required for every good composition some purpose or moral, some rational answer to the question, *why was this picture painted?* In the illustration just attempted, the moral purpose would be to inculcate humanity and compassion. This might be its effect perhaps upon the sympathies of a person who had never read the parable of the Good Samaritan. But upon the mind of a practical Christian moralist such a composition, well sustained throughout, would be apt to have complete effect. The eye also of the educated spectator might be gratified by remarking the natural, the unaffected, the dignified, the nting.

(278.) Respecting the moral purposes of the Art, we take pride in the observation that our English School has never pandered to the vices of profligate patronage. "The depraved eye of sensuality," observes Sir Martin Shee, in a Work to which we have made frequent reference, "must, for such panders, look to the profligate imbecility of other nations." Those golden words therefore, of his great predecessor, Reynolds, have not fallen to the ground. "The good and virtuous man alone can acquire a true and just relish even of Works of Art. The same habit of mind which is acquired by search after truth in the more serious duties of life, is only transferred to the pursuit of lighter attainments. The same desire to find something steady, substantial, and durable, on which the mind can lean as it were, and rest with safety, actuates us in both cases. The subject only is changed."

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(279.) ii. The next branch of the subject of composition, according to our division of it, refers to the *choice of objects to be represented*, and requires the student to select those phenomena of Nature which will be most effectual for the purposes of his Art.[*] We have already, under "outline," given some elementary acquaintance with the forms of objects. A selection from those forms for the purpose either of Painting *history*, *portrait*, or *landscape*, is to be made by the composer.

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For *historical* subjects a constant study of the antique, and familiar acquaintance with the best engravings after the great masters of the Roman School, will have prepared the student, when he comes to view his model in Nature, for rejecting all that is unessential[*] as well

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graceful, or (as far as truth and strong emotions would permit,) not ungraceful expression given to the prominent characters in the scene; as well as by discovering a faithful representation of appearances peculiar to the oriental or Syrian clime, whether depicted in the features, costume, and bearing of the several figures, or in the wild scenery and sultry atmosphere of a route infested by robbers between Jerusalem and Jericho. Lastly, another class of admirers might be those whose acquaintance with the Art would enable them to appreciate the picturesque or artistic arrangement of forms, lights, shadows, and colouring. The achievement of a victory over some great technical difficulty has with some such beholders too often compensated for absolute insipidity and want of meaning; or, what is infinitely more abominable, for grossness and impurity.

[*] The extraordinary Work of Leonardo da Vinci on Painting, which we have so often had occasion to mention, contains on the subject of selection from Nature more written information than has been added by any single artist since his time. His Treatise, though apparently unfinished, and put together without method in the form of notes or memoranda, may be termed a guide to Nature not only as to form but chiaroscuro; and has actually guided the most eminent who have succeeded him. It is truly observed, in an excellent artistlike publication (4to. 1827) from the pen and graver of Mr. John Burnet, under the modest title of *Practical Hints on Composition, Light and Shade, and Colouring*, that "he (Da Vinci) may be said to have laid a foundation for principles that are to be traced through the works of the best colourists to the present day."

Sir Joshua Reynolds, in his Notes to Du Fresnoy's *Art of Painting*, declares, that all the rules which the theory of Du Fresnoy or any other teaches, can be no more than teaching the Art of seeing Nature. In another place he remarks, that to see "at sight," is not a gift in every one's possession. "The life of a student," says the author before quoted, "who has not accustomed himself to a proper mode of arranging his observations, will be spent in an endless search of what is continually passing before his eyes." Burnet's *Practical Hints*, part ii. p. 43. Milizia, the ingenious author of *l'Arte di Vedere*, under the term *Composizione* in his *Dizionario delle Belle Arti*, thus expresses a similar opinion. *Il dono piu raro nella composizione è la scelta* (selection.) *La Natura si presenta a tutti: è quasi la stessa a tutti gli occhi. Ma vedere è poco, discernere è tutto. L'artista egregio sa sceglier meglio ciò che gli conviene.*

There are two distinct methods of selection which seem to characterise two of the greatest masters of composition. One is that of taking the form and proportions from Nature so as to obtain accurate individual likeness, and afterwards of using such gestures, and such modifications of expression and muscular action as the taste and judgment of the artist may be competent to supply; omitting at the same time every circumstance irrelevant, or not necessarily concerned in the subject of the work. This appears to have been the practice of Raffaelle, of whom it was a maxim to paint men not so much as they are, but *as they ought to be.* His practice was *con meno ottinere il più.* The other method is that of taking the entire *expression* from some model in Nature, (not, of course, a sitter for the portrait, nor conscious that the Painter is "taking notes,') by careful and profound examination of the habits and emotions of the individual so represented. According to this latter method, many of the gestures may be ungraceful and sometimes may not be absolutely necessary to the action required; but that the expression is true to Nature cannot be disputed, nor is it possible, if grandeur and symmetry of form be superadded, (and its application be appropriate to the subject,) to avoid admiration of its originality. This appears to have been the practice of M. Angelo. Our own great moral Painter, Hogarth, did this; but without the *grand* superaddition which indeed his style did not admit of. For a comparison of Raffaelle with M. Angelo, see Reynolds, *Works*, vol. i. p. 128; Opie, *Lectures*, p. 41—52; and Fuseli *passim*.

The efficiency of the latter of the above methods we could illustrate by one or two familiar cases within our knowledge. A dead subject lay upon a table as a model for some academic students. The question was how to dispose it in the best manner for drawing from it as the study of a lifeless figure. Many attempts were made unsuccessfully. At length one of the number proposed the ingenious plan of letting it fall from the table. This was done; it was suffered to fall on the ground, where from the various action of the law of gravitation on all its parts it immediately assumed a striking and a natural attitude. (Art. 264.) Another case happened to a very able English artist now living. He was employed, while at Rome pursuing in earlier life his professional studies, to paint a picture from the horses as they prepared to start on the Corso. He accordingly took his station on the morning of the race at the most convenient point of view which his patron had taken care to provide him; and during the interval of some minutes previous to the start he had time to sketch the horses together with the men holding them. In front of them was the cord across the street to restrain the animals until the signal should be given. He had just finished a preliminary sketch when the signal was made, the cord removed, the race begun: and he had opportunity for a few seconds to watch the action of the animals at the moment of being loose from the control of the men who held them. Here was the spirit and fire of natural action. He watched and sketched rapidly, while the first impression was yet fresh in his immediate thoughts, the play of the limbs, head, neck, chest, &c. Afterwards in his studio sitting down to compose the picture, he found his second sketch far exceed his first; and he selected from it, consequently, the best part of his composition. His employer, a gentleman of taste and discernment, though well satisfied with the finished work, requested to see the drawing in question; and preferred it to the finished picture. The relater of this anecdote, in the enthusiasm of his pictorial reminiscences of Italy, always winds up with an axiom, that "the less man has to do with the placing of God's creatures the better. While the horses remained under the control of art and of human management they exhibited no striking expression; but the moment they got loose their natural character appeared."

[*] It is remarked of Raffaelle, (confessedly the greatest master of expression yet known,) that he always has contrived to render himself intelligible by means few and simple, in preference to such a method as would exercise the ingenuity of his spectator to discover his meaning. It is in this respect that we think he differs most from his stupendous rival, and we may add instructor, M. Angelo; whose compositions are of that high, philosophical, Pindaric, Dantesque description which addresses and captivates chiefly the profound thinker, the learned, the original observer. If a professorial chair was established in 1373, at Florence, for the express purpose of explaining the *Commedia* only fifty-two years after the death of Dante; we need not wonder that now, in the XIXth century, two hundred and sixty-seven years after the death of the Painter of one of the noblest yet most mysterious flights of imagination that ever was conceived, namely, the "History of Man from his Creation to the Final Judgment," on the ceiling and walls of the Capella Sistina: some previous *initiation* should be desirable for the spectator in order to his undivided enjoyment of the daring sublimity of Michael Angelo. The compositions, certainly, of Raffaelle require less the aid of comment, if indeed they require any comment. They possess a kind of Homeric simplicity calculated to endure till

as all that is irrelevant or injurious to his composition. He will preserve simplicity and *unity*. He will group his figures with a view chiefly to the story of which he is to make a pictorial version.* Faithful to this principle, he will not scruple at occasional repetition of the lines and contours whether of drapery, of limbs, or features, where the intensity of the one sentiment expressed demands uniformity of expression.† He will distinguish, however, in his repetitions between similitude and sameness. He will not tolerate insipidity. *Variety* is often as essential to a composition as unity. A contrast will be shown of waving or curved lines with others straight or less curved. (Art. 263, 264.) The motions and posture of the limbs will vary with the character of their owner.‡ Feebleness will be contrasted with strength; age with youth; childhood with manhood; feminine delicacy with manly vigour. The varieties likewise of passion and of sentiment* are

Unity, variety, and fitness in the choice of objects.

Poetry, and Painting, and Sculpture shall be no more. It is more than probable, also, that the great sculptile talents both of Raffaelle and of Angelo, but especially of the latter, contributed mainly to their astonishing facility and success in depicting any position or representation imaginable of the human figure. The Cartoons supply admirable exercises for the modellist.

* The late Mr. Northcote (whose name, we regret to say, may now be added to our short obituary (see PAINTING, p. 498.) of English worthies in Art) has some very applicable remarks in his *Life of Titian*, concerning the Roman School. He observes that its amateurs and patrons among whom the ancient taste predominated sought only for the most heroical subjects: and therefore the chief endeavour of the Roman artist was to make things with the greatest possible simplicity. "It is," adds the venerable author in another passage, (vol. i. p. 387.) "the test of genius, or good sense, to prove with how few figures it is able to tell the story. And I should give it as my advice to students in the Art, always to compose their historical designs with as few figures as possible, admitting that their subject be fully explained; and also that their figures should be large in proportion to the size of their canvass. The reason is, that it will better enable them to master the greatest difficulties and display the highest refinements of the Art which are most assuredly comprised in the human figure. An experimental lesson of most useful tendency would be to tell the story even with one solitary figure, after the example of Michael Angelo, if it be within the bounds of probability, or at least with such an intention in the mind. This method would oblige the student to give the figure the most decided contour, with precision of form and drawing, energy of expression, and every characteristic mark which may be required towards its explanation. It must force him to apply to those things only for assistance which are of essential importance to his work, and will prove at the same time how necessary it is to keep clear of all impertinent and trivial matter, such as might confuse and perplex the subject, or lead the spectator to mistake it for what was not designed, and deceive him into a wrong conclusion. An historical picture, like an enigma or riddle, should have this property, that if on viewing it the specific subject is not made determinate, at least it should not be found to answer to something else."

† M. Angelo is unrivalled for preserving unity in his figures. If all the limbs, and muscles, and features, that are available in his figure are sometimes called into action, they are all, however, always directed to *one* action, always faithful to one combined movement.

‡ There are many works of the early German and Flemish masters, such as Durer, the Van Eycks, &c. which are excellent models of every variety of expression. The figures and forms throughout are evidently faithful transcripts from Nature and may be relied upon. Give them symmetry, colour, chiaroscuro, and other *adjuncts* of good Painting, and they must be found an inexhaustible treasure from which future Raffaelles may borrow without scruple and without blame. And although in expression, particularly of the countenance, there are national peculiarities which should be avoided; yet there will be seen in such works as we allude to, much of the grand general human character, and of that universal dialect, (so to express it,) the proper dialect of a Painter, common to all nations. Respecting the varieties of individual character in Historical Painting, it is recommended by Mengs in his chapter *della Composizione*, that the student should confine his acquaintance with the story of his subject only to some choice passages in a favourite Historian: but that he should obtain every circumstance, by reading or otherwise, that he can possibly collect; as well of the personages in his picture, as of his hero, in order to represent them adequately, or (to use our own term) *individualize* them. *Opere di* Mengs, vol. i. p. 286

* Notwithstanding the ridicule which some (who only write or talk of, and do not attempt the arts of design) have attached to treatises for representing the varieties of human emotion, and who have termed them "receipt books for the passions," there cannot be any doubt that such studies are anatomically, as well as in some small degree metaphysically, important to every artist that claims to be superior to a house-painter, and to be a student in the school of animated nature. The Work of Le Brun has been censured by Winckelmann as portraying with a most outrageous pencil the affections, and the lines of passion: and as being therefore likely to mislead artists, and young artists more especially, into extremes; instead of drawing their attention to those delicate gradations of expression which distinguish every work of genius. Severely just as this censure is, there is no denying, at the same time, that to this system of Le Brun many able artists have been indebted for elementary knowledge. If he was not infallible, he was at all events a very honest instructor, and exemplified in his own works his own precepts. In those works we certainly see nothing of the sublime. But he designed with perfect correctness, and understood completely all that mechanism could effect. Besides, in a popular treatise, the utmost that can be done seems to consist in marking distinctly the stronger and more vehement signs of emotion, and contrasting them with the peaceful state. Intermediate shades of expression may be left to the ripening judgment and future experience of the young observer. The Essays of Sir Charles Bell on *Anatomy of Expression*, to which we have before alluded, are replete with admirably bold and pointed examples. Camper, in the Work we have quoted, (Art. 222,) has an ingenious Lecture on the subject. "The first thing requisite," says he, "is to acquire an accurate knowledge of the form of the skeleton, and particularly of the cranium: the second to be well acquainted with the principal muscles of the face and their action: thirdly, to trace the nerves in their divisions and connections with these muscles. An oppressed, sorrowful, or melancholy person, lets his head sink downwards, or he supports it with his hand. The equipoise is no longer maintained by the muscles of the neck: that is, the nerves belonging to those muscles are rendered inert. A lively, contented laugher, on the other hand, raises his head, and his breast is agitated." p. 128, 129.

Lavater, in his Treatise on Pictorial Anatomy dedicated to Fuseli, mentions the system of Bardon by which the different states of mind to be represented are divided into four classes:—the tranquil, the agreeable, the sorrowful, the violent. He thinks this division more philosophical than that of Watelet in his Poem on the subject; but regards the latter as more practical. Watelet has six principal classes. 1. Sorrow, or pain of mind. 2. Joy. 3. Pain by bodily suffering. 4. Defection, prostration, or imbecility, mental and bodily. 5. Energy, mental and bodily. 6. Privation of a good or of a pleasure. We omit the subdivisions, which the reader will not find much difficulty to supply, and proceed at once to keep our promise (Art. 232) of enumerating those muscles of the countenance which relate more especially to *expression*. For this purpose we will suppose the student to be prepared, according to our suggestion in Art. 257, (note 2.) with an outline, or Painting of the fore part of the human skull. He will begin with those muscles that lie deepest, and so proceed to the external layer nearest the skin. 1. The *buccinator* (so called from its prominence in the act of blowing the *buccina*, a circular trumpet) will extend from the root of the coronoid process of the lower jaw, and thence along the alveolar processes of both jaws, as far forward as the dentes canini: to be inserted into the angle of the mouth, which it draws backwards and outwards, or contracts its cavity by pressing the cheek inwards. Its action is to assist the tongue in collocating food between the teeth for mastication: also in blowing, to form, by its dilation, a large space for containing air; in order afterwards, by its contraction, to press or force out from the lips the quantity of breath so collected. For the air in blowing is not collected in the throat, but in the reservoir of the mouth as just described. On the buccinator lies a small portion of fat, which fills up the deep space in the cheek. When this fat is reduced by sickness, the cheek takes a hollow form, and the action of the strong muscles above becomes more prominent. 2. The *temporalis* we have already mentioned. (Art. 232.) 3. The *masseter*. (*Ibid.*) 4. The *levator menti* vel labii inferioris arises from the lateral incisor of the lower jaw to be inserted into the under lip; and is called *superbus*, from its throwing up the under lip with a contemptuous expression. 5. The *depressor labii superioris alæque nasi* arises from the alveoli of the incisors of the upper jaw, and from the root of the canine tooth to be inserted into capable of most interesting contrast. But, thirdly, besides unity and variety, *fitness* will be maintained: namely, a careful attention to the probabilities of the story. To this effect, appropriate dress, decoration, or

the upper lip, and root of the ala nasi or nostril, and draws the upper lip and the nostril downwards. 6. The *depressor labii inferioris* (from its square form called quadratus menti) arises from the side of the lower jaw, to be inserted into the edge of the under lip, which it pulls downwards. It covers the muscle No. 4. 7. The *depressor anguli oris* (called *triangularis* from its shape) arises from the base of the lower jaw, to be inserted into the angle of the mouth which it depresses. It partly covers the last-mentioned muscle. 8. The *levator anguli oris* arises on the upper jaw, between the root of the first molar tooth and the foramen infraorbitare, to be inserted into the angle of the mouth, which it draws upwards. It partly covers the buccinator. 9. The *zygomatici* (major and minor) arise from the zygomatic processes of the cheek bone, to be inserted into the angle of the mouth. They draw the corner of the mouth and upper lip obliquely upwards and outwards. They almost cover the last-mentioned muscle. 10. The *levator labii superioris proprius*. From the external orbiter process of the upper jaw immediately above the foramen infraorbitare, to be inserted into the upper lip, which it is employed exclusively in raising, as its name proprius implies. 11. *Levator labii superioris alæque nasi* arises from the superior nasal and orbiter processes of the upper jaw to be inserted into the outer part of the nostril and upper lip. It raises the upper lip and dilates the nostril. 12. *Orbicularis*, a sphincter muscle, or series of circular fibres, forming great part of the fleshy substance of the lips. It closes the mouth, and is in direct opposition to the surrounding muscles, for all the levators and depressors of the lips are opponents and antagonists to these circular fibres the growth and formation of which is supplied chiefly from the muscles inserted into the lips. 13. The *compressor naris*, arising from the outer part of the nostril and adjacent part of the upper jaw, to be inserted into the lower part of the os nasi and nasal process of the upper jaw. Its office is to close or compress the nostril by drawing it towards the septum nasi. Or in junction with the lower fibres of the frontalis, (Art. 259.) not yet described, it pulls the nostril outwards. It also corrugates the nose.

The above-named muscles relate entirely to the nose and mouth. The remaining three concern the eyelids, eyebrows, and forehead. Previous to depicting them, each of the eyeballs may be now presented in its orbit or socket. 14. The *corrugator supercilii*, a transverse slip of muscle that knits the eyebrows, has a fleshy origin from the internal angular process of the os frontis. It is to be inserted into that inferior fleshy part of the frontalis, which forms the skin under the eyebrow. It pulls down the eyebrows and skin of the forehead, and produces vertical wrinkles. 15. The *orbicularis palpebrarum* arises from the internal angular process of the os frontis, from whence its fibres spread round the orbit, and cover first the upper and then the lower eyelid, with the bony edges of orbit. "There is," observes Sir C. Bell, "a little tendon in the inner angle of the eye, which may be considered as the fixed point for this muscle, both origin and insertion. Some anatomists describe it as two semicircular muscles." It closes the eye by bringing down the upper lid and lifting the lower. It also compresses the eyeball and lachrymal gland. 16. The *occipito frontalis* has its origin from the occiput from whence it spreads in a tendinous fascia (Art. 259) over the crown of the head, forming the scalp, but again becomes muscular on the lower part of the forehead and on the brows, till its insertion into the skin under the eyebrows, and also into the internal angular process of the frontal bone in the inner angle of the eye, while another slip passes down over the nose. It pulls the skin of the head backwards, raises the eyebrows, and corrugates the skin of the forehead. "Independently of its action, the mere fleshiness of this muscle gives character. The brow of Hercules wants the elevation and form of intelligence; but there will be observed a fleshy fulness on the brow and around the eyes. This conveys an idea of dull brutal strength." *Anat. of Expression*, p. 58. For some of the more remarkable of the above named muscles, see plate ix. Having now gone over those regions of the eyes, nose, and lips, in which, as has been truly said, lies the focus of expression, we will next proceed to describe as succinctly as we are able, with the assistance of the Works we have quoted, some of the more remarkable expressions indicated by the movement of these facial muscles. In a tranquil and unruffled state of the countenance, the muscles No. 14, 15, 16, are poised, and counteract each other. When the eye is shut gently, as during sleep, only the upper eyelid moves. The eye is opened also only by an attachment from No. 15 to the margin of the upper eyelid. It is by the action, says Camper, (p. 132.) of the seventh pair of nerves that we laugh, blush, or look pale. The muscles No. 8, 9, 10, 11 raise the mouth, fill the cheek, and express cheerfulness. No. 13, however, is an antagonist to these. "In all the exhilarating emotions the eyebrows, the eyelids, the nostril, the angle of the mouth are raised. In the depressing passion all this is reversed, the brow is clouded, the nose peculiarly arched, and the angle of the mouth depressed. The parts of the human face most movable and most expressive are the inner extremity of the eyebrow and the angle of the mouth, and these are the parts which in brutes have the least expression. In these features, therefore, we expect to find the muscles of expression peculiar to man. Bell's *Anat. of Expression*. No. 14 is the most remarkable of peculiarly human muscles. It knits the eyebrows with a meaning that irresistibly conveys the idea of mind and sentiment. Rage is indicated by scintillation of the eyes, and by the snarling muscles, No. 10, 11, exposing the canine teeth. (See *Mammalia*, plate v. for an excellent example in the Wolverine.) This expression by itself would show brutal rage, but assisted by No. 14 the appearances of human thought and emotion are superadded. Again, to indicate mere animal or bodily pain, let No. 12 half close the lips, which are at the same time inflated. But join to this the action of No. 6 and 7 (particularly of the latter, which is peculiar to man) and an effect is shown of more than mere bodily suffering. In this expression, of course, the action of No. 14 and 16 will combine. The expression of laughter is produced by the relaxation of No. 12, and consequently the preponderance of the elevating muscles No. 8, 9, 10, 11. There is a seeming resemblance between the action of muscles in laughter and in weeping, or mere bodily pain, but the character of the cheek and lips presents a striking difference. No. 12 in a smile is merely relaxed, whereas in anger and in pain it is forcibly drawn by the other muscles. In violent laughter, No. 9, and the other elevating muscles, are yet more excited, and No. 12 yet more relaxed. In contempt, pride, suspicion, jealousy, No. 12 combines with No. 4 and 7 to arch the lips and depress the angle of the mouth. The lips are drawn horizontally with a bitter expression, which just discloses the teeth. In grief, No. 7 and 14 (the former by depressing the angle of the mouth, the latter by the upper inversion of the eyebrow) combine to show a dejected and subdued state of the mind. In short, the angle of the mouth and the inner extremity of the eyebrow (features most indicative of human expression) are the most movable parts of the face, and at these points the facial muscles may be said to be concentrated. In languor, faintness, or sorrow, the muscle No. 7 is often accompanied by the action of No. 14, and the latter combined yet further with the action of the central fibres of No. 16. In this expression the depression must be slight, not violent, for No. 7 cannot act strongly without the combination of the superbus No. 4, which would completely spoil and change the expression. In the languor of sickness, when suffering is not extreme, the nostrils are depressed. But an occasional pang dilates them, (by means of No. 11,) causes gnashing of the teeth, (by No. 2 and 3,) widens the lips, (by No. 6. 10, 11,) raises the eyebrow, (by No. 16,) fires the eye, and gives a swelled flush to the whole countenance. In fear, the expression of the human subject is, as of other animals, without dignity. The eyeball is much exposed, the eyebrows elevated to the utmost, the breathing irregular, and, as it were, by gasps, or suspended, the nostril inflated: to which symptoms add the convulsive opening of the mouth, exhibiting partially the teeth and the tongue together with the dropping of the jaw and hollowness of the cheek. For an attempt, on a very small scale, to exemplify some varieties of expression, see plate ix. The eighth pair of nerves, observes Camper, or the lesser pathetics affect the system in emotions of surprise, of love, and in the approach of dissolution. In dying, he continues, the eyes are drawn towards each other, because the power of the will ceases, and the muscles only act in consequence of the feeble remains of life yet seated in them. The eighth pair, or greater pathetic, communicates with the throat, breast, abdomen, and by the intercostal muscle, with the nerves of the arms and legs. P. 132.

It might not be difficult to pursue at greater length an abridged view of the effects of emotion and of nervous excitement upon the neck, the trunk, and the limbs. But we must here conclude this branch of study, that we may have space for pointing to others equally indispensable to the student, remarking only on the importance of his giving peculiar attention in his figures to the action of their hands. It has been observed of the celebrated "Cenacolo" by Leoni da Vinci, of which an excellent copy is preserved in the Royal Academy, that were the heads in that Painting entirely hidden, equipage, and observance of costume in general will contribute. The manners and exterior of each figure will represent clearly, though unobtrusively, the age, rank, sex, condition, and character of the individual. It must, however, be all along borne in mind, that the outlines of a composition must have reference also to the effects that are producible in the arrangement of chiaroscuro and colour hereafter mentioned.

The arrangement to be suited for the best aids of colour and of chiaroscuro.

(280.) But more especially in Portrait Painting, the necessity of accommodating the outlines, or beginning of a composition to the ultimate effects of chiaroscuro and colour is obvious. Such an outline from Nature is to be chosen as will contribute to represent the "best looks" of the person painted. The rules of unity, variety, and fitness are also as essential to this kind of composition as to any other. The first of these qualities requires that the general character of the person should be preserved.* The second demands such force of contrast as, without interfering with simplicity or unity, will promote individual likeness, and at the same time gratify the eye. The third quality of a portrait, or its fitness, presupposes in the artist a degree of address seldom attainable; which must enable him to hold unlimited control over the taste of his sitter in what relates to dress and to costume generally.

(281.) It is chiefly, however, in landscape, and in Paintings of what is termed "still life," that the grouping of outlined objects must be made a preparation for the effects of light, shadow, and colour. Objects in Nature that interfere with, or combine awkwardly with the parts of this subsequent process, must not be selected for landscape, or must be excluded. In historical forms or in portraits a particular sentiment, or set of features, may require a particular outline, and to that outline must the future choice of colour or of effects of shadow be made in some degree subservient in order to a good likeness or a forcible expression of the sentiment intended. But it is in landscape, or the representation of inanimate objects, that the aerial perspective, the chiaroscuro, or the disposition of local and reflected lights, colours, and shadows, must be all in all. And although, in such pictures, there is a certain degree of unity, variety, and fitness* to be observed in the forms which such a composition *puts together*, yet the chief interest of such objects for Painting must arise from good choice and arrangement of colour.

Of Composition.

Appearances of Nature to be studied and selected as to light and shade.

(282.) Composition of light and shade comes next to be considered. An acquaintance with the perspective of shadows† is essentially necessary to the student, as well as with the appearance of light either *reflected*‡ from the surfaces of objects according to their degrees of polish,§ or refracted through them, according to their degrees of transparency, and their fitness for transmitting colours and forms seen through them.‖ (See OPTICS, p. 410. 417. 422; LIGHT, Art. 4, 5, 36, 88—108. 151, 171, *et seq.*) The earliest attempts at representing light and shade among the ancients appear to have been given in what is called monochrom painting, viz. by

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and the hands only of the figures exposed to view, the spectator might discover the story, and sympathize with the actors in that pathetic scene of affectionate energy, surprise, dismay, and reverential sorrow.

That the limbs and whole person must cooperate with facial expression the commonest observer will allow. We are inclined to an opinion, that sometimes variety of expression may even be given to a head only by varying the position of the neck which supports it. The head, for example, in plate xi. fig. 2 (if the dotted lines ϴ ϴ be taken for the boundaries of the neck,) is represented looking up, and seems to wear an attitude of entreaty. If these dotted lines be removed or concealed, and Δ Δ be taken to represent the neck, the eyes appear looking no longer upward, but forward, as if during conversation with an equal. Thirdly, if Π Π be made the boundary lines of the neck, the face directs a downward look towards some supposed object below with an air of protection to an inferior. In this example, therefore, without changing the position of any one feature of a face, the reader will perhaps agree with us that the changes only in the adjoining parts contribute to give three different peculiarities of expression to the same unaltered countenance. For fine expression of hands see in the National Gallery the picture by Da Vinci of "Christ among the Doctors." Also, by Giorgione "The Martyrdom of St. Peter." And in the Dulwich Gallery the "Adoration of the Shepherds" by An. Carracci; together with several fine works of N. Poussin, particularly the "Triumph of David;" Guercino's picture of the "Woman taken in Adultery," and a picture said to be by Rubens, of "Samson and Delilah."

* Sir Joshua Reynolds remarks of the Dutch School of Painters that they have still more *locality* than the Venetian. "With them (the Dutch) a history piece is properly a portrait of themselves; whether they describe the inside or the outside of their houses, we have their own people engaged in their own peculiar occupations; working or drinking, playing or fighting. The circumstances that enter into a picture of this kind, are so far from giving a *general* view of human life, that they exhibit all the minute particularities of a nation differing in several respects from the rest of mankind."

* Fitness of costume in composing a landscape may be said to be its adherence to one particular class or style, as well as its freedom from local incongruities. It would be absurd, for example, to confound in the same landscape the Arcadian style of Claude or of Titian, or the classic solemnity of Gaspar Poussin, or the wildness (often overwrought and studied) of Salvator Rosa, with the more detailed and more homely, but no less able and beautiful works of the elder and younger Teniers, of Ruysdael, Hobbima, and the Dutch and Flemish Schools of Landscape. Again, with respect to local incongruities it would be equally absurd to place aquatic plants in a waterless desert, or to plant trees from the Torrid Zone in a composition extracted from Windsor Forest.

† See Note (A.) at the end of PAINTING.

‡ See Note (B.) *Ibid.*

§ Da Vinci (cap. 131 and 132.) observes respecting the local colour of bodies, that those which have rough and uneven surfaces discover most their natural or general hue. The colour of polished surfaces, on the contrary, is with difficulty discernible. These last are tinted by the colour of the light reflected from them, (whether primitive or borrowed,) by the glow for example of a morning or evening sun, by the blue of the sky, &c., and he instances in the smooth and shining leaves of trees and herbage, when seen from a particular point of view. Further examples may be added from interiors in the yellow and red light of a lamp or of fire, &c. reflected from the shining surface of any coloured object.

‖ Examples of every day occurrence are before the eyes of the student. The interposition of air gives to distant objects that blue cast which, in Southern climates, where vapours are more rapidly exhaled than in ours, is of intense clearness and brightness. In all climates, however, the lower portions of the atmosphere are, in some degree, vapoury, and therefore less transparent. But the upper portions being less dense transmit rays with proportionate distinctness: so that objects generally exhibit more or less of their local colour and of the effects of light on their surfaces according to their degree of elevation. (See further on this subject Da Vinci, cap. 68, 69. 128. 134. 136.) Not only the air which veils or envelopes every object, is itself a medium more or less transparent, but almost every object which it envelopes is more or less adapted for transmission of light. Let almost any piece of coloured drapery be held up between the spectator and the sun: the apparent colour of the cloth will be affected by the transmission of the rays. Light also penetrating the edges or issuing through the crevices of wood, or even of stone, (especially of marble,) exemplifies this property in bodies still more distinctly. Every leaf of a tree, every petal of a flower exhibits, according to its position with respect to any light which illumines it, similar translucent properties. With respect to animate objects: not to mention the wings and bodies of innumerable insects, the feathers of birds, or the hair of other animals, let the observer only hold up the palm or back of his hand against a strong light, with his fingers extended and placed laterally close to each other, he will discern between them a peculiar warm flesh tint caused by the passage of rays through the transparent skin. An attentive examination of these and similar effects in all their varied gradations is important to good colouring.

gradations of white and of some one dark pigment, such as brown or black.* No further effect seems to have been desired than would result from pieces of sculpture seen from one point of view. The same course may be said to have been pursued by all subsequent artists, as being introductory to the representation of variously coloured objects. The effects of moon light, indeed, often afford, in nature, admirable subjects for nearly monochromatic pictures. This portion, accordingly, of the study of chiaroscuro, has been, in general, separated from that of colour, in order, it should seem, to simplify the theory on which depends mainly, and often entirely, the success of a composition. That the darkest shadows are almost, if not altogether, without colour, is obvious to the experience of every eye; but to look at Nature without uniting colour to the brighter parts of objects, or rather to those parts which are in half-light, and in which colour is most conspicuous, requires careful discernment. The successful labours, however, in innumerable instances, both of the graver and of the portcrayon, prove this practice to be sufficiently attainable.†

(288.) Light and shadow may be considered in four ways: either

1. As giving relief, or bringing forward to view the prominent parts of an object. Thus, the features of a countenance, the fingers of a hand, the folds of a garment, the leaves and twigs of a bough, &c. are so many details of which the outlines alone would present the figure or object to which they belong under the appearance of a flat surface, but which filled up, as in Nature, with alternate lights and shadows, according to the relative position of some illuminating body, strike the eye, and through the eye the imagination, with an impression of their solidity.‡

2. As giving relief to some complete, some detached, some isolated object, by raising its contour, or outward boundary, off the ground, composed of other objects which appear from behind or beyond it. In this way, the figure of a horse, a man, or a tree, is relieved by the sky seen on the other side of it, or by a mountain, or building, or by distant masses and groups. Or one building is relieved by another building, one tree by another tree, &c.*

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* Fuseli quotes as follows in his introductory Lecture, p. 8. from the conjectures of Riem on the Painting of the Ancients, 4to. Berlin, 1787. Their *monochroms*, he says, or "Paintings of one colour on a plane or tablet," were "primed with white and then covered with what they called punic wax, first amalgamated with a tough resinous pigment, generally of a red, sometimes dark brown or black colour. In or rather through this inky ground the outlines were traced. From this step "they advanced at last to masses of light and shade, and from those to the superinduction of different colours." See also our present Treatise at p. 467.

† A white or a black object being of the same local hue with the colouring material of the monochrom must be peculiarly and often most inopportunely conspicuous. Two things are to be done in monochromatic works. 1. To represent the proportion of light and shade in any part of an object supposed uniform in its local colour. 2. To represent among a number of objects, each of which has a different local colour, the exact value in Nature which each local colour bears as to light and shade, when compared with the rest.

It is well known that living specimens exist of individuals whose eyesight cannot distinguish colours, and who see all objects in this monochromatic light. Such a faculty (if we ought not rather to say deprivation) might be serviceable for determining what pictures would have the best effect in an engraved form. For it not unfrequently happens that a well-coloured composition before being submitted to the graver undergoes considerable changes under the direction of the artist who composed it in order to pictorial effect under its new monochromatic garb.

The following communication of an experiment by M. Homberg, made at Paris, in 1699, to the French Academy of Sciences, may give some idea of the comparative value of light conveyed from coloured objects. *Il prit un verre bien brut de deux côtés et par conséquent peu transparent, et l'ayant placé dans une ouverture par où passoit toute la lumière qu'il recevoit, il ne voyoit au travers de ce verre que les objets blancs qui étoient au delà et nullement ceux de toute autre couleur. Ayant un peu poli le verre, il vit mieux le blanc et commença à voir le jaune: et à mesure qu'il le polissoit davantage, les différentes couleurs commençoient à se découvrir dans cet ordre—jaune, vert, rouge, bleu, noir. V. Histoire de l'Acad. Roy. des Sciences de Paris. Année*, 1699. *Physique Générale*, p. 18, 19.

‡ Respecting any natural object selected for pictorial imitation, the artist must beware of confining his representation of it (through a misplaced ambition of originality) to the impressions of his own mind alone. He will find, that for obtaining faithfully the characteristic lines, lights, and shadows of any object, he must be on the watch for and set down not what is most recondite, but what is most obvious: not the peculiarities which he may chance to pride himself for discovering, but the peculiarities which nobody can avoid seeing. In short, he will select whatever is predominant; whatever cannot fail to reach the eye of the commonest observer. Those very characteristics, which from their commonness may in Nature be little valued, become, when transferred to works of Art, invaluable. It is remarked of Rembrandt that he gave to every object the peculiar character familiar to every spectator. The student will likewise be careful to see his object or model in such lights as will exhibit best its predominant features. There is always in Nature, observes Da Vinci, some light in which an object is better recognised than in any other: some light in which an animal figure, for example, exhibits best the particular muscles required to be in action. He instances the difficulty of recognising even the face of a familiar acquaintance, if instead of being illumined in the way we usually see it, it be made to receive light only from below. He desires always such a point of view to be chosen as will show both the shadowed and the enlightened side of any figure: and recommends a high light, uniformly diffused, and not excessive nor glaring, as most advantageous for showing features and minute parts. We need only add, that similar remarks hold true of inanimate substances: and that in the case of buildings, for example, some point of view should be chosen opposite their main angles or corners, in order to have the advantage of light contrasted with shadow. (Da Vinci, cap. 40, 41. 279.)

* The shaded side of the object which casts the shadow is commonly less dark than the shadow which it casts. Thus the shadow of the wall T P K O z R (plate xii. fig. 4) will be darker than the wall itself. The causes of this are various. One is, that there is commonly some reflected light from a neighbouring object; as in the present instance, from the enlightened part w H $d\,j\,k$, &c., a reflex is thrown upon T P K O z, &c.: another is, that reflexes from bright clouds, or a bright sky opposite the sun would likewise be thrown upon it: and another is, that supposing no wall or interposing object whatever at H, there would yet be a reflex from the illuminated part of the ground.

A difference important to the student may here be remarked between the lights and reflexes of an out-door scene and of an interior. "The principal mass of light in out of door scenes (both in Nature and the best masters) is generally placed in the sky, or upper part of the picture;—in interiors it is generally reversed, the roof and back-ground being reserved for a mass of shadow and repose." (Burnet, *On Composition*, p. 12.) The admirable interiors of Ostade exemplify this latter effect in almost every variety that ingenuity could devise: an effect which the observer of Nature will explain by considering that the great vaulted roof or dome of the sky becomes, by day-light, a source of general illumination which descends more or less on all objects below it: but that the ceiling of a chamber often receives only such reflexes as arise from the floor or side walls, which, being more in the way and more opposed to the *descent* of ordinary light through the door or windows, must receive more of the direct rays. Hence, whatever be the colour of our walls, or furniture, or carpeting, our ceilings are almost always white, in order, it should seem, that no reflected light may be absorbed or lost to us, but that as much may be drawn as possible from above us. (See note (C.) Obs. 53, at the end of PAINTING.)

On the subject, therefore, of *detaching* objects from their ground, the observation of Da Vinci is applicable in this place. Figures, he says, exhibit a much greater relievo, when illumined by a particular than by a universal light. For a particular light will cause reflexes which loosen and *detach* the figures from their ground. These reflexes are imparted from some of the group from whom the light rebounds upon the shadowed sides opposite them of the other figures; and faintly illume those sides, so that such shadows, however forcible and effectual, will have no hardness nor harshness, but

3. As being influenced by the various transparent media through which light passes, and more particularly by the air, either in proportion to the density of the latter, or in proportion to the quantity of atmosphere interposed and giving dimness more or less to the greater number of objects seen at one view, (and, consequently, represented covering the greater part of any picture,) according to their distance from the spectator. Thus, groups of trees, or cattle, or other figures, or of rocks, or cottages, will be observed in Nature to have their lights and shadows more faintly expressed than other groups or masses which are viewed through clearer and purer air,* or through a smaller body of air, by reason of greater nearness to the eye. (Art. 262.)

The first and second of the above considerations will be found chiefly to concern the separate parts of a composition, while the third applies especially to the general effect of it as a whole, and to the proper keeping of each part,† as conducive to that general result.

4. A fourth consideration is, that light and shadow are also influenced by the local colour of the illuminated object. The lights of black drapery, for example, will be far darker than the shadow of yellow cloth, or of white linen. And there will be perceived in every colour, according to its intensity, or its place in the prismatic scale, a greater or less capacity for reflecting light. (OPTICS, Art. 66, 67, 68. LIGHT, Art. 1139. 1141.) This latter observation will be of further use when we come to the means, modes, and rules of pictorial representation. For the present we remark that the three last of the above divisions comprise the principles of chiaroscuro.

(284.) Colour, pictorially considered,* as it appears

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will fall off and lose themselves by an insensible gradation. He elsewhere adds, that this light partakes of the colour of the body reflecting it, and will be greater in proportion to the nearness of the reflecting surface. (Da Vinci, cap. 55. 124. 127. and Note (C.) Obs. 49, 50, 51 at the end.)

* The practice is not uncommon of confounding the general term chiaroscuro with the ordinary acceptation of the terms light and shade. In light and shade, commonly so called, consists the mere art of shading correctly any object by itself. Chiaroscuro includes much more. To chiaroscuro belongs the general arrangement and effect of lights and shades, tints and demitints, throughout a picture. *Il chiaroscuro*, says Milizia, *non è soltanto in ciascun oggetto, ma è il risultato di tutti i lumi, di tutte le ombre, e di tutti i reflessi d'un quadro. Artisti*, he exclaims, *dilettanti, amatori, spettatori, studiate Correggio, miratelo, rimiratelo, godetelo, e saprete che cosa è chiaroscuro. Saprete che il chiaroscuro è la base dell' armonia, e i colori non sono che i toni che servono per caratterizare la natura de' corpi. Dizionario delle Belle Arti*, p. 187.

A painter, then, besides observing and seizing the best light for exhibiting the individual parts of any object, must also contemplate it in conjunction with all the other objects which surround it. There is continually to be found upon the great theatre of Nature, a favoured spot where some one of her innumerable *dramatis personæ* stands out most conspicuously and effectively beyond the rest. The *stage-effect* (if we may presume so to call it) which is thus naturally produced, must be carefully analyzed and studied. It will be found to consist in the diversified application of some of the plainest and simplest truths imaginable. Dark objects, for instance, appear most prominently upon a light ground, and light objects upon a dark ground. The latter, too, though of the same size with the former, appear larger; that is to say, a black square relieved by white seems smaller than a white square of the same area relieved by black. Or, again, as a dark surface receives breadth (Art. 294) by surrounding a darker one, and *vice versâ*, so does a bright surface by the intervention of a brighter, which forms, as it were, its focus. As the first mentioned of these instances gives contrast and *variety*, so the last conduces to *unity* or general effect.

† *Keeping* means such a correct disposition of the lights, shades, and colours of an object as leaves the mind of the spectator in no doubt as to its intended place in the picture. In Nature, every object in this respect is perfect. Nature all the while continually varying in the direction, colour, and intensity of lights and shadows, presents no object that does not *keep* its due position, its proper value and prominency in the scale of aerial perspective. One of the most indispensable employments of the artist is to study the effects of atmosphere throughout all the various changes which diversify the appearances of objects. "The atmosphere," observes Mr. Craig in a Lecture to the Royal Institution, "is transparent in a greater or less degree, according to the quantity of vapour with which it is charged, or the position in which we stand with regard to the light. We find that glass, and even crystal or diamonds, may be so doubled and redoubled as not to allow the possibility of distinguishing objects through those media; because the particles which compose them, though pervious to light in a very great degree, are also susceptible of a certain portion of shadow. It is even so with the atmosphere, the thinnest and most transparent of all media. When the air is highly illuminated by the sun, and we stand with our backs to the light, distant objects of any kind are scarcely discernible, because we see the enlightened sides of the particles composing the medium. If then the particles of air can obstruct and reflect light, they must also be liable to have their shadows; combining these particles, therefore, of lights and shadows, or of black and white, the colour of atmosphere will be grey, varying a little as the one or the other predominates. The effect of this medium, consequently, is, to make lighter every thing that is darker than its colour, and to darken every thing that is lighter, till, each approaching the other, the objects become so many flat screens, and at last, from a continuance of the same cause, totally disappear. The principle, acted on by some artists, that the interposition of air makes all objects lighter, (and that, therefore, the brightest part of the sky must be always brighter than any object in a picture,) would be true if all the objects in all the distances of a landscape were actually in shadow; because they are then darker than the colour of the atmosphere, and must be made successively brighter by its interference. But to show," continues the author, "that this is not always the case, I beg the favour of you, in the first opportunity of a bright day to take a piece of paper or any white object, and, standing full in the light, bring the paper in apparent contact with the whitest cloud you can find in the sky. You will perceive that the paper is many distinct degrees whiter than the cloud."

* The "high aspiring" Painter, who would enter the lists with Nature, must take his weapons from the same armoury. He must employ all his faculties of vision, whether physical or intellectual, in observing how objects receive increased effect from their being viewed in some particular position, in some particular light, or in some particular combination with other objects. After all his pains, however, he will find himself necessarily deficient in the art of representing perfect relievo on any plane surface. "The practice of Painting," as has been well remarked, "can never be carried higher than to represent truly the highest possible degree of created Beauty, always in Form, sometimes, nay frequently, in Colour; but never in the full vigour of light and shadow." Craig's *Lectures*, p. 107. But we may here also notice how painfully every artist, in his imitations of Nature, must be sensible that he often differs from his brethren, and often from himself, in possessing at different times very different degrees, not of intellectual vision only, but of the faculty of sight which he is called upon to exercise in this profession. He will find his eye not always faithful and uniform in its decisions, and more particularly with regard to the subject of colour. An ear for music has been always thought essential to the musician: though all musicians confessedly have not the same acuteness in that organ. But a bad ear may be often improved; not so often a deficient eyesight. Whether it be that the musician by possessing a written language for his instrument, and a gamut in which the intervals of sound are arbitrarily measured and defined, and brought under mechanical dominion, can thus call up to his ear at any time, any given interval of tone; whereas the Painter to decide his interval of colour has no such artificial help, but trusts to his eye only for measuring his gradations of tint, tone, and hue in natural objects: certain it is, that differences among musical artists are far less remarkable than among the pictorial, not only as to modes of practice, but even as to elementary principles of composition in their respective Arts. Besides the great varieties of talent shared by different individuals in the same branch, there are shades of eminence for one and the same artist in different branches. Some musicians have an excellent ear for *time*, but are less perfect in respect to *tune*. Analogous to this is the distinction among Painters, between an eye for *form*, or great facility and taste in drawing; and an eye for *colour*, which is often

Appearances of Nature as to colour.

in natural objects, conduces much to the same purposes as light and shade. It enables the eye to recognise objects and gives them prominency. By the student in Art, colour may be most conveniently regarded either

1. As a property of light issuing from self-luminous bodies.[*] Thus the rays of the Sun are seen, at different periods of the day, to spread a different tone of colour over any prospect: so also the red light of a fire, or the yellow light of a candle will give to any scene in a chamber a peculiar warmth of tone.[†]

2. As belonging also, under the denomination of local colour, to other substances opaque or transparent, or polished. Examples are scarcely needed. With respect to transparent substances it is seen that in proportion to their transparency is the vividness of their local colour when light shines through them. Thus the local colour of leaves, though it may be dark green, becomes of a lively brightness by their being seen in situations up against the light, and in which the light passes through them to the eye. But of opaque polished substances it will be observed that they seldom or never exhibit uniformly their local colour.

3. As forming reflexes cast from one coloured sub-

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found unconnected with the other talent. Again, there are some performers who modulate with great beauty and felicity a *melody* or succession of single sounds, while others have greater power in ascertaining and executing *harmonious* combinations of them. To the former of these we may compare the artist who is successful in effects of light and shadow by the use of white contrasted with some one dark pigment; to the latter we may resemble the profound colourist, who, in company with Correggio, can traverse with a sure and clear eye all the mazes of chiaroscuro,

Untwisting all the chains that tie
The hidden soul of harmony.

It is, however, an encouraging fact, that constant practice improves a *good* eye. The student thus gifted should be in the daily habit of colouring from Nature. The benefits of this habit are to be seen in the superior discrimination of every good Portrait Painter on the subject of colour. Such a one may even have no eye for the general proportions of the human form nor of any thing beyond the natural shape of the human head; but as a colourist he will probably excel much better draughtsmen. The advice of Sir Joshua Reynolds, to make coloured sketches in preference to drawings merely pencilled or shaded in black and white, conduces to the same end. The only danger is, that the young colourist may run into a fault which has been well termed *modelling* a picture, and may be satisfied with a hasty process instead of careful previous outline and tasteful academical arrangement. (See Note (D.) at the end of Painting. But let the youthful Professor only give daily attention in an equal degree to the sublime of Art, as well as to the detail of Nature, and his Titianesque execution will be worthy his Raffaellesque designs. Reynolds has suggested also a mode of composition by taking some one figure from a celebrated master and designing others to correspond with it. An air of grandeur is thus imparted to the whole work. If by a somewhat similar process, particular objects in a composition be gleaned from different scenes in Nature the selection will likewise amply repay the gleaner's industry. Many Painters have pursued the custom of modelling their groups for the purpose of obtaining a true representation of light and shade. Tintoret and Correggio are known to have availed themselves of this method.

[*] See Note (A.) def. 2. at the end of Painting.

[†] Tone (from τείνω, *tendo*) refers, in its original application, to the tension of strings in Music, in order to produce sounds. Supposing a string or wire severed into two equal parts: and the two strings thus formed to be stretched exactly to the same degree of tension; their sounds will have no interval between them, that is, the sound of both will be one and the same, or unison. A greater or less degree of tension in one of the strings will produce a greater or less interval of sound between them: one will have a higher and the other a lower tone. So, in Painting, intervals of shadow and of colour are greater between any two objects in proportion to the warmth, sharpness, decidedness, and distinctness of the one, and the greyness, coldness, neutrality, or faintness, of the other. The Art, therefore, of *toning* a picture is the process of giving to each interval of colour and shadow, its proper and natural value in any picture. There is the following difference, however, between the Musician and the Painter. The former has a fixed scale not copied from any natural phenomena, (unless the singing of birds may be so called,) but determined arbitrarily according to an arrangement of such sounds as, from experience, are found pleasurable: whereas the Painter copies from a scale of colouring and shadowing that actually exists and has at all times existed in Nature. The variety indeed of these tones of colour in natural objects is wonderful. It is infinite. Light, both in its hue and intensity, is continually changing. The same object viewed at different hours in the day has a different tone of colour. In the course even of a few seconds a variation in the direction of the Sun's light may completely alter the whole prospect. Not only lines and contours which were lively and bold may become retiring and feeble, but the whole of the scene may have a tint of blue, red, or yellow, or some combination of them (Art. 284, 285) thrown over it in an instant. Painters have here a great difficulty to encounter. Their tints and tones cannot of course be changed simultaneously with those rapid changes in the natural objects before them. If a Painting could be executed as quickly as the rays are cast in a camera upon a dark wall, then, indeed, the Painter might be said to catch the fleeting colour as Poets are said to "catch the Cynthia of the minute." But the Painter must be satisfied with an artificial arrangement established as nearly as possible upon principles conformable to the appearances in Nature. As in Nature there is a degree of relief and *warmth* (Art. 284, No. 5) in proportion to the nearness of any object to the plane of the picture; to the kind and degree of light upon it; and to the proximity of some other object enlightening it directly or by reflexion: so, in Painting, these are the principles of successful imitation though so frequently departed from. At the commencement of a picture those parts only will probably receive the chief care of the probationer in Art, and will be, as indeed they ought to be, most strongly defined and marked which are of the greatest importance, while the other portions of the work will be left in a less obtrusive and a broader state. But as the work proceeds the proper subordination of these minor portions is often most injuriously disregarded. "It is," observes an able artist and writer, "the general character of an object that is most important, and this character is to be preserved at the price of every other quality. It is this which is imprinted on the mind of every one, and is therefore paramount to all other properties."

And as in Nature there is throughout the whole of any scene a general tone of colour pervading the air according to the point of time when it is viewed, so, in Painting, the artist must have one prevailing hue which pervades in imitation of the atmosphere the whole picture, one prevailing tint which gives it character. This, like a key-note in Music, must mark and signalize the entire composition, and though, in Music, other tones and modulations into other keys are continually made, and other tints and other colours require, in Painting, to be introduced; yet the one prevailing key must reign throughout.

In copying from Nature the Painter has the advantage of choosing, among the multiplied appearances of the same object, that appearance in shade and colour, which, without altering its form, may render it most agreeable. In this selection he must study Harmony of Colouring. Here is another phrase from the vocabulary of the Musician. As, in Music, certain tones, when sounded together, blend agreeably according to a scale fixed and drawn from experience; so, in Painting, certain colours and tints are known to blend harmoniously with others. Also as, in Music, discords and harsh combinations arise from certain intervals of sound striking the air at the same moment; so, in Painting, violent painful and startling effects arise from *unnatural* juxtaposition of certain colours. We say unnatural, because in all appearances of Nature, (that is, in all appearances out of the Painter's canvass,) there is a wonderful effect of harmony caused by the intervening and circumambient air; which, by its one prevailing *tone*, overcomes in most instances all jarring and violent opposition between any two objects placed near each other even of the most glaringly discordant colours. This seems effected by an apparent mingling or union of the rays of each at the respective points of contact of the two objects, and is aided by the grey of distance caused by the intervening air which appears to neutralize the colours otherwise harshly opposed.

From this proceeding of Nature the Painter collects a method of *toning* his picture and reduces it to one harmonious effect as a whole. Greys are an important medium by which he must work to neutralize and subdue all uncalled for harshness in colouring; and for the same end a compound tone mixed from the two opposing colours may be introduced to qualify his greys for the undertaking.

stance upon the surface of another.[*] Thus, though the local colour of leaves be green, yet such of them as reflect the blue of the sky will have bluish reflexes; while others that reflect the rising or setting light of the sun will have reddish or yellowish reflexes.[†]

4. As having various degrees of *strength* or of paleness, which implying more or less shadow, make prominent the parts so shaded, (Art. 283,) and give us ideas of solidity. Thus by moonlight, or in the white or greyish light of noon, with the sun veiled in clouds, a piece of drapery, according to its lights and shades, exhibits numerous tints[‡] of one and the same local colour, sufficient to convince us of its being a solid body, though far less conspicuous than in sunshine.

5. As contributing to give prominency by its *warmth* to certain objects, or by its coldness, to throw back certain other objects into distance. Thus the blue tones[§] of a mountain or of a building, assure us that a quantity of atmosphere intervenes, while certain warm tones intermingled at their summit convince us of their elevation. Similar effects are found in all objects proportionably to the power of light.

(285.) But colour, besides giving identity and prominency to objects, has a further qualification, that of giving pleasure to the eye by certain agreeable combinations of coloured rays.[||] An acquaintance with these, however, comprises, as any student may soon find, but a slight portion of the knowledge of Painting. It amounts to little more than the ability of producing, by the juxta-

Of Composition.

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[*] See Note (A.) def. 3. at the end of PAINTING.

[†] See Note (C.) on reflexes of colour.

[‡] By *tint* we would be understood to mean a particular degree of strength or of paleness in any colour. Thus in the diagrams to illustrate the prismatic and compound scales of colour, (plate xi. fig. 5 and 7,) the strongest tint of colour is at the inner circle numbered 20: the palest at No. 1, or the outer circle. The student (to whom we recommend to construct the figures considerably larger, and to colour them for himself) will observe that there are twenty different shades or degrees of strength reckoning from the whitest to the deepest intensity of each of the eighteen tones.

[§] By *tone* we understand the interval (see the third Note to Art. 234) between two colours as to degrees of coldness or of warmth. (Art. 296, 297.) Thus purple is a warm colour when compared with blue; and a cold colour when compared with red or yellow, &c. In like manner, green is a warm colour compared with blue; and a cold colour when compared with yellow, red, orange, &c. The degree of difference is termed a tone, and this degree might perhaps be marked like any point in a mariner's compass, (see plate xi. fig. 5 and 7,) if the circle were so divided.

[||] The warm colours (yellow, orange, red, and their compounds) are understood to attract, and seemingly to approach the eye; on the other hand, the cold colours (violet or purple, blue, and green, with all compounds of blue) are considered to give the appearance of receding. We here subjoin a brief abstract of the theory of Moses Harris, published about 1781, with a dedication to Sir Joshua Reynolds, who gave it his approbation. The opinion of the greatest colourist of the English School gives the system a strong claim to our attention. Harris divides his scheme into two parts:

1. The prismatic scale or division, (plate xi. fig. 4, 5,) admitting no other colour but those shown in the prism.

2. The compound division, producing all the other colours to be found in Nature.

Pursuing the Newtonian view, he regards white and black as colours: white, a perfect combination of all as representing light; and black, as also a combination of red, blue, and yellow, in equal force and of the strongest powers. He conceives these three equals, by equally opposing each other, to be each of them destroyed, so that none of them is distinguishable, but all become absorbed in total obscurity. To illustrate this, he supposes the three primitive colours to meet in their fullest powers or strength in the form of three triangular pieces of stained glass, placed over each other to verify the effect. (Fig. 4.) He conceives that precise and clear ideas of the three primitives and of their mediates may be conveyed by reference to some known substance or flower.

Primitives	red,	vermilion,	wild poppy.
	yellow,	king's yellow,	butter flower, or meadow ranunculus.
	blue,	ultra-marine,	cornbottle flower.
Mediates	orange,	red orpiment,	garden marygold.
	green,	sap-green,	leaves of the lime tree.
	purple,	——	hairy sweet-scabious, or the flower of the common Judas tree.

1. Respecting the first division, or prismatic circle, (fig. 5,) yellow, red, and blue being the simplest elements, take their places at the greatest distance from each other in the circle. Between these respectively are placed the mediates, *viz.* orange, green, and purple. For if red and yellow be mixed, they will produce an orange, and therefore it is placed between red and yellow: if yellow and blue be mixed, green is produced, and accordingly takes its place between those two colours. In like manner, purple produced by blue and red, must be placed between them. A gradual change of the colours will be observed when viewed successively from the top towards the right. Red will be seen softening gradually into orange; the orange to yellow; the yellow to green; that again to blue, which graduates to purple. The purple coming to the upper part of the circle is lost in red, which completes the whole. In this scale it is manifest there cannot be a colour composed of more than two of the primitives. The number of colours in this circle are eighteen. Each of these is divided by concentric circles into twenty parts, or degrees of power, from the deepest and strongest to the weakest, or from the outermost circle to the innermost. These degrees are called tints, of which the whole circle contains 360, ($18 \times 20 = 360$.) So that each of the colours in the innermost or smallest circle has twenty degrees of power, while each of the outermost possesses only one.

2. The division, or scale named compound, (fig. 7,) is supposed to contain all those colours which may possibly be made, where all the three primitives are employed conjunctively. In order to effect this possible combination, the three mediates, orange, green, and purple, are substituted for the three primitives, red, yellow, and blue. Each of the mediates being composed of two primitives, will, according to the example of the first diagram, (fig. 5,) and by the same mode of proceeding, produce other compounds and their tints, which in this second scale (fig. 7) (exclusive of the orange, green, and purple included in the prismatic) amount to 15 colours, and when each is divided into 20 degrees of power or strength, will produce three hundred tints, which being added to the 360 containing in the prismatic scale, form a total of 660; yet the colours producing so great a number of tints amount to no more than 33, ranged in such a natural order, as easily to be retained in the memory.

Prismatic. *Red*, orange-red, red-orange; *orange*, yellow-orange, orange-yellow; *yellow*, green-yellow, yellow-green; *green*, blue-green; green-blue; *blue*, purple-blue, blue-purple; *purple*, red-purple, purple-red. Compound. *Orange*, olive-orange, orange-olive; *olive*, green-olive, olive-green; *green*. slate-green, green-slate; *slate*, purple-slate, slate-purple; *purple*, brown-purple, purple-brown; *brown*, orange-brown, brown-orange.

"This systematic arrangement will be found of use in contrasting colours. If a contrast is required to any colour or tint, look for the colour or tint in the system, and directly opposite you will find the contrast wanted: *viz.* suppose it is required to know what colour is most opposite or contrary in hue to red; look directly opposite to that colour in the primitive scale, (fig. 5,) and the contrast is found to be green, which is the compound of the two other primitives. So likewise the diametrical opposite to blue is orange, and to yellow purple."

The author proceeds to remark the usefulness of his theory to the process of mixing or blending colours. Many do not admit of being mixed together without producing a negative, neutral, or unmeaning colour, *viz.* green and red of four degrees of tint; blue and orange of five degrees; yellow and purple of six degrees. "But if the colours so mixed are possessed of all their power, they then produce a deep black, as all opposites in either scale will do. No pure colour can be so formed. Therefore any two colours, in order to produce a third by their mixture, must not be chosen at so great an interval or distance as one-third of the circle. The nearer they are situated the better. Suppose an orange colour wanted, red and yellow will effect it; but red-orange and yellow-orange mixed will do much better."

Likewise if the colour of a picture, or any part of it, be too position of certain colours, the same sensation as by a well-composed nosegay or by the wing of a butterfly.

(286.) Another use of colour is its suitableness for conveying or encouraging certain sentiments, that may be in conformity with the intended moral of a picture. We do not here enter into nor recommend the emblematical purposes to which colour was applied by antiquity and by the early Schools of Art.* But there is evidently in colours as well as in sounds, a sentimental tendency. The blind man, who likened scarlet to the sound of a trumpet, was not untrue to Nature. Some colours awaken cheerfulness and gaiety; some invite to repose and peace; others excite ideas of grandeur and splendour; some challenge rivalry and hurl defiance,† while others diffuse impressions of a solemn character, such as of reverence, of contemplation, of loneliness, or of melancholy.

iii. Means, rules, or modes of representation.

(287.) iii. We come now, lastly, to the third consideration which ought to occupy the mind of a composer, namely, his *means*, *rules*, or *modes of representation*. These are so numerous, and in such variety, according to the genius of each individual artist, and the nature of the vehicle he employs, that to enumerate them completely would be like describing every kind of musical instrument, together with the peculiar merits of every remarkable performer upon each. The few particulars which our remaining space permits us here to collect, may assist towards a useful system of practical composition.* In order to as plain and compendious a statement as possible, we give a summary of these particulars in the following rules: and observe,

Pictorial licenses.

(288.) That, in a Historical arrangement, the inventive powers of the composer, like those of a Dramatic Writer, should be directed to every probable circumstance which may contribute to heighten the effect, and which, though in strict truth it did not happen at the time, yet might have happened, without doing any violence to probability. For example, it is a Historical fact that General Wolfe, when he fell at Quebec, commanded such officers as

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strong, for instance too red, or too yellow; the same consideration of the author's scheme points out a remedy, by uniting in the case of redness its opposite, *viz.* green of the same tint or degree of power with the red; and in the case of yellowness by uniting purple of the same power with the yellow. He then observes upon the difficulty of finding materials to give a perfect example of his scheme: but adds, that indigo, gamboge, carmine, and sap-green, may be called perfect, because each of them contains the twenty degrees of power, or even more. He conceives, that if his colours were divided into a greater number of tints or divisions, such an attempt would rather give greater confusion than utility to his arrangement. We may add, that the reader may easily make the attempt for himself by composing a third scale, of which the three intermediates, brown, olive, and slate, shall be the factors instead of the mediates, orange, purple, and green. (Fig. 6.) The experiment, indeed, has been actually made and published by the ingenious Mr. Hayter.

* We read in *Exodus* of garments of blue, purple, and scarlet; which colours either from their simplicity or forcible qualities, have been employed by artists of all ages in painting draperies of sacred or noble characters. Colours also have a fitness according to the several personages represented. Thus we read of "the azure zone of Venus, of the sea-green garments of Neptune, and the red mantle of Mars." Burnet, *On Colour*, p. 38. "Yellow," observes Mr. Craig, "is understood to represent lustre and glory; red to represent power and love; blue implies divinity; purple, authority; violet, humility; and green servitude. Upon this statement and explanation we are enabled to account for the invariable practice among Painters of portraying the blessed Saviour of Mankind in garments of red and blue: the red implies his comprehensive love to the human race, as well as his power to fulfil the dictates of that love; and the blue signifies his Divine origin." *Lectures*, p. 175.

† "There are," observes Mr. Payne Knight, "some kinds of birds and quadrupeds, such as turkeys and oxen, to whom scarlet is peculiarly painful; as they will run at it, and attack it with the utmost virulence and fury. Green, on the contrary, appears to be grateful to the eyes of all animals; though colours, as well as sounds and flavours, are more pleasing when harmoniously mixed and graduated, than when distinct and uniform. Indeed they are almost always graduated and broken in Nature. In every individual pink or rose, whether its colour be white, yellow, or red, infinite varieties and gradations of tint are produced, not only by the different modifications of light and shadow, but by the various reflected rays which one leaf casts upon another, according to their different degrees of opacity and exposure." Knight, *On Taste*, 8vo. 1805, p. 62.

"Colours that are most agreeable to the eye are such as the eye has become accustomed to from their being constantly presented to the sight; such as blue, white, or grey in skies; green in trees and grass; brown or warm grey in earth, road, or stone. As therefore the eye has been formed upon the contemplation of such colours, the general look of Nature can be given only by admitting large portions of such colours into the picture; if they are more vivid than are most commonly observed in Nature, the charm is destroyed. All colours rendered familiar by the introduction of artificial means are guided by the same laws. A green, though quite unnatural when employed upon herbage, might be strictly natural in representing the local colour of a piece of drapery; yet we may safely admit that the most brilliant colours may receive an advantage in being toned to those hues most common in Nature, especially if they form a large mass in the picture." Burnet, *On Colour in Painting*, p. 5.

* Next to being keenly susceptible of such impressions and appearances as are proper for Painting, the artist must possess to a high degree, the faculty of *methodical arrangement*. Having chosen his subject, he must be further gifted with a genius to contrive its execution. To knowledge and intuitive perception of whatever is grand, beautiful, or interesting in visible objects, he must add familiar acquaintance with the means and materials of his Art. It is not enough to have his picture designed, completed, and hung up only in the gallery of his fancy. Any dreamer can paint thus in his sleep, and can surpass any thing that ever was done before in Painting. But the work of the waking artist must be substantial and tangible. The "airy nothing" must have a local habitation, adequate to its reception; systematically, carefully, and durably constructed.

System, with Painters, has a twofold operation. It relates, in the first place, to the intellectual impressions to be conveyed to the spectator. This includes the knowledge and use of expression; on this head we have already offered some remarks. (Art. 279.) Or, secondly, it relates to the materials for conveying these impressions, *viz.* outline, light and shade, chiaroscuro, colouring, grouping, &c. System arrives at its highest excellence when the latter of these two operations is not seen nor noticed in comparison of the former. In Raffaelle, for example, the expression is so intelligible, so direct, so forcible, that you forget the contrivances and materials by which that great master accomplishes his purpose. To any one, not a Painter, the most *expressive* performances seem the easiest. The gifted artist, however, well knows the pains, the ingenuity, the skill, and judgment exercised for their accomplishment.

For the general mediocrity of modern Art, a very good practical reason has been assigned. Moderns have more taste than genius. As it is the province of genius to make her own rules, not hastily, but with all the circumspection of a superior being; to create, if we may so express it, a world of her own, but at the same time to regulate her creation by the laws of strong sense drawn from the code of Nature, and judiciously adapted to circumstances: so it is the fatal peculiarity of taste to follow no rules but what are ready made. Taste fluctuates. Taste seems to live only by the breath of fashion. To-day what is extravagantly praised becomes insipid to-morrow. Taste would improve upon Nature. Hence we see that style has been so often more favoured, more trusted to, and more studied than natural expression; and that Schools of Art have failed to benefit and advance the cause which they profess to maintain.

Genius, on the contrary, continues true to Nature, and like Nature is always various, always interesting or exciting. It happens in Painting, as in Music, that genius is guided chiefly by Nature; but that taste without genius tends to draw the eye as well as ear away from Nature to the performances of other artists that have been successful competitors for fame. It tends to induce a habit in one artist of copying from another, instead of pursuing a system carefully digested, and previously established for himself; the result of his own experience and industrious observation of natural phenomena, as well as of the labours of others.

were about him to leave him, and continue their pursuit of the enemy. The only persons who remained with him when he died, were the surgeon and a grenadier who attended him as his servant. West, however, in his celebrated picture, "The Death of Wolfe," has, with great ability, introduced various other figures, which give to view a number of interesting associations connected with that event. The Indian chief, in particular, who watches the expiring hero, acquaints us with the place where the scene is laid and identifies it with American History. Copley's "Death of Chatham" is a similar example. The Lords appear in their robes. The fainting fit also of Lord Chatham (for he did not die in the House of Lords) was not actually witnessed by many of the persons introduced, for the sake of scenic effect, into the picture. Cases might also be mentioned where two events which happened at the same time are introduced into the same composition. Of this, "the Transfiguration," by Raffaelle, is an instance. It was while our Lord was transfigured in the Mount, accompanied by St. Peter, St. James, and St. John, that the remaining nine disciples were implored by the afflicted parent of the demoniac to heal his son.

Of Composition.

(289.) That a similar exercise of taste and fancy is not only admissible, but is essential to picturesque arrangement in grouping* objects, whether animate or inanimate. The position of the figures, the direction of the light, the formation of masses to give breadth, (Art. 294,) and of contrasts to give variety, are not necessarily such as did occur at the time of the event, or scene to be painted. It is sufficient that they might, without improbability, have occurred.

Five general gradations of light and shade.

(290.) That light and shade may be most conveniently divided into five parts or gradations, namely, No. 1. Extreme light; No. 2. Half light; No. 3. Middle tint; No. 4. Half dark; and No. 5. Extreme dark.* These gradations may be expressed by five tints of some one colour taken from either of the scales compound or primitive, (plate xi. fig. 5 or 7,) supposing the colour to be whitest when most approaching to extreme light at the outer circle, and deepest or darkest when approaching to extreme shadow at the inner circle. Between these two extremes of the twenty shades of tint there mentioned, let the space be divided by five. The extreme light, or No. 1, will then lie between the outer

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* "In commencing a composition, it is customary to mark the middle of the space, for the purpose of arranging those points we consider of most importance to the subject; dividing the picture for the regulation of the masses of light and shade, ascertaining and fixing the horizontal line, &c. A mode of constructing the composition in reference to a diagonal joining any two corners of the picture is often suggested from the perspective effect requiring a length of line, thereby obliging us to place the point of sight at one side of the picture; sometimes it is suggested from the group requiring a large space; which a diagonal line secures, as in the 'Elevation of the Cross,' by Rubens; or sometimes it is suggested from the conduct of light, as in his picture of the 'Descent from the Cross.' Cuyp, adopting this mode of composition in most of his pictures, (which are generally sunset or sunrise,) places the focus of light at the bottom of the sky, thereby enabling the distant part of the landscape to melt into it by the most natural means; while the strongest part of his sky, being at the opposite angle, produces the greatest expanse, and mixes and harmonizes with the dark side of the picture. Thus the eye is carried round the composition till the two extremes are brought in contact, the most prominent with the most retiring. In compositions constructed upon this principle, (particularly where the landscape occupies a large portion,) many artists carry the lines of the clouds in a contrary direction, to counteract the appearance of all the lines running to one point; thus using the dark of the clouds to *antagonize*, as it is termed. By such a practice, an apparently better equipoise may be produced, but it sacrifices many advantages. For we observe in many of the pictures of Cuyp, Rubens, and Teniers, where the figures, landscape, and sky are all on the same side of the composition, that a rich and soft effect is produced; and that the strong light and dark touches of the figures tell with great force against a background of houses, trees, &c., which are prevented from being harsh and cutting by mixing their edges with the clouds, or dark blue sky. This doubling of the lines (if I may so express it) gives a picture that rich fulness which we often perceive in a first sketch, from its possessing several outlines. Those who imagine that by thus throwing the whole composition on one side, a want of union will be produced, will be convinced of their error by perceiving (in any work thus constructed) how small an object restores the balance. Since the smallest object by being detached and opposed to a faint background of extreme distance receives a tenfold value."

"Raffaelle, in the 'Transfiguration,' has made the principal figure of the lower group (an interesting young female) detach itself from the ground by a strong warm light cutting against the shadow, and by a dark blue mantle coming in contact with the light. From the circumstance of her addressing the Apostles and pointing to the demoniac, the two sides are united; and the figures are so linked together that the eye is carried round until we arrive at the most projecting points, namely, the hands and feet of the Apostle with the book. The disciples express their inability to perform the cure, while two of them, pointing to the Mount, refer the people to Christ; and thus connect the lower with the upper half of this sublime picture."

"It is not only necessary that a group should have hollows for the reception of shadow, but also projections for the light to rest upon; it not only ought to possess a good general form in the outline which defines it, but the figures must also be linked together in such a way as to lead the spectator in amongst them. They must appear to have room to stand upon, and every figure must keep its appropriate place, according to its relative distance from the eye. Hence a form of composition by a concave or convex line has been often adopted as the simplest and best, and possessing the greatest variety of advantages. That it is so generally used may cease to surprise, since we find it applicable both to the regularity of Raffaelle and the irregularity of Rembrandt." Burnet, *Practical Hints on Composition*, p. 10, 11. 26, 27.

* We translate as follows from Raffaelle Mengs, in his *Rules of Painting*. "To facilitate the balance of colours in a picture, and to regulate it suitably to the kind of composition chosen. I repeat what I before alluded to, in regard to *five* classes of materials for representing all the appearances of Nature; namely, five tints of colour. Of these five, two belong to the lights and two to the darks. The other is a middle tint, which I call the purest of the five, as not belonging either to light or dark, but receiving and reflecting both in an equal degree. If out of these five materials, the Painter uses only two, and completes his picture by means of white by itself and black by itself, a confused effect will result; because white as well as black has the property of excluding every other colour; the former in the lights; the latter in the shadows. But if by the mode I am endeavouring to explain, a certain proportion of these two be taken, sometimes a higher degree of black, sometimes a higher degree of white, and sometimes a middle tint, a pleasing variety will follow, notwithstanding the uniformity and monotony of these two colours."

"A juxtaposition of the two extremes will give force, asperity, or hardness. A large interval of middle tint extended between them will soften that hardness; and further, a careful arrangement of the different tints, so as to place each degree, if possible, between the one above and the one below it in the scale, preserving only sufficient distinctness for a correct representation of the objects painted, such a mode of operation will cause the greatest imaginable softness and sweetness."

"Again, by a separation of lights into masses with other lights and of darks with other darks, a picture may obtain an appropriate air of gloom, or of grandeur. (*Resterà mæstosa e grandiosa.*) And, lastly, by adaptation and combination of these means in all their endless varieties, any effect, clear and lively, or crude and confused, or expressing softness, tenderness, or any other sensation may be produced. If to this effect of light and shade, the varieties of colour be added, in accordance with the same principles of composition, (*colle stesse rugioni,*) the effect will be infinitely heightened; but the colourist must beware of repeating too often the same lights and the same darks in equal form or in equal quantity upon his picture, and must also shun carefully all violent extremes. He must give his whole attention to truth and verisimilitude. He must remember that chiaroscuro is the foundation of what is termed harmony, and that colours are only tones which characterise the forms of bodies." *Lezioni Pratiche.* *Opere di* Mengs, tom. ii. p. 275.

circle and the circle marked four shades or degrees of tint. The half light, or No. 2, will lie between the circles of four and of eight degrees; the middle tint, or No. 3, between the circles of eight and of twelve degrees; the half dark, or No. 4, between the circles of twelve and of sixteen degrees; the extreme dark, or No. 5, between the circles of sixteen and twenty degrees. But it would, perhaps, be a not less correct illustration, and more in accordance with general practice, to express the highest light by positive white between circles one and four; the extreme dark by positive black between circles eighteen and twenty; and the intermediate three tints by degrees of black and white mixed; No. 2 having most white, No. 4 most black, and No. 3 an equal portion of each.

(291.) That a picture consisting chiefly of No. 1 and 2 gives opportunity for objects containing the extreme black, or No. 5, to stand out with great force and clearness; but strength of colour (which may be said to perform the office of No. 3 or 4) will be requisite to prevent feebleness, and to give a full firm effect to such a composition. This effect of colour is frequently exemplified by Cuyp, in his clear and beautiful, and at the same time substantial representations of broad bright day.

(292.) That if No. 4 and 5 compose the greater part of a picture the objects of No. 1 will be proportionably brilliant, but they will be apt to stare, and have the fault of spottiness, while the remaining objects will be buried in obscurity. Here again intermediate demitints (often the effects of colour) interpose to give breadth and richness.

A picture of this latter kind, of which the greatest proportion is composed of No. 4 and 5, is said to be painted in a *dark key;* as a picture composed principally of No. 1 and 2 is said to be painted in a *light key.*[*]

(293.) That if the greater part of the picture consist of No. 3, a fair field is open both for the higher and lower divisions of the scale to display an equal degree of prominency; but in this case there is danger of monotony, of sameness, and of such regularity of gradation as will not give due consequence to the principal object. Insipidity, however, may be obviated by extreme lights or darks, judiciously and strikingly introduced. Suppose, for instance, the ground of a picture to be of middle tint, or No. 3, joined with half dark, and over this ground let the *extremes of light,* No. 1, be introduced; some degree of harshness may occasionally happen, which must be tempered and softened by No. 2. Let, on the other hand, the *extreme of dark,* No. 5, be laid upon a ground of No. 3; this ground of middle tint will by the contrast be rendered more in union with No. 2. (Art. 306.) Let, thirdly, the extreme dark have a place on No. 4, or the half dark, the small interval of gradation will occasion breadth, and softness, and repose. (Art. 295.)

Breadth how effected.

(294.) That in proportion to the extent of light and shade, will be the degree of breadth in a picture.

Breadth of light will be effected by an omission of so much of No. 3,[*] or middle tint, (Art. 290, 293,) as will leave larger space for No. 1 and 2. This kind of composition is most adapted for scenes of daylight, during which, in Nature, the darkest shadows (or those of No. 5) are most cutting and conspicuous, from their being most isolated. (Art. 305.)

Breadth of shadow is obtained by allotting the largest portion of surface in a Painting to No. 3 and 4. This is the practice of the Rembrandt school. It is adapted admirably to interiors, to appearances of moonlight, of storm, and "darkness visible," and finds agreeable employment for the imagination of the spectator, who, under no restriction from regular outlines, or contours, may give such shapes as he conceives most suitable to mysterious, indefinite, unarticulated forms.[†]

As breadth of light has been most aptly termed the Allegro of Painting, so breadth of shadow maintains the character of Il pensieroso.[‡]

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[*] Pictures painted in a dark key possess many advantages which have led our greatest colourists to its adoption; but as low-toned pictures are apt to look heavy and black, unless richness of shadows or sharpness of lights be preserved; so pictures painted on a light key are apt to look flat and unfinished without the greatest circumspection. In Nature, the intense light of the sky, and the atmosphere filled with its innumerable refractions, spread a luminous character over the whole scene. To represent this, the artist can only employ a greater degree of whiteness, a very inadequate quality. Hence the difficulty of imitating the splendid brightness of mid-day, or the brilliant effects of an evening sky. In treating the one, unless the delicate varieties of the half lights are attended to with the greatest care, the picture will look crude and unfinished; for the tints being so nearly allied to each other, the exact sharpness to define them, and their exact tone, either by repeated scumbling, or mixing them to the proper tint in the first instance, require the nicest attention and most refined study; otherwise the shadows will be powdery instead of pearly, or the lights white instead of luminous. In the other arrangement mentioned, (*viz.* for the glow of evening,) the yellow tones may become solid and foxy, if deprived of the delicate cool tints so necessary to prevent their appearing too hot, and to give the whole that tremulous unsteady appearance which light possesses in Nature. "Light pictures," continues Mr. Burnet, in his *Treatise on Chiaroscuro,* "from the tenderness of their light and shade, require the colours opposed to each other, whether blue opposed to red, or yellow to cool grey, to be managed with the greatest delicacy; otherwise their strength will destroy all appearance of light and air."

In light pictures strong colours can stand only as middle tint, or for leading the light into the shade, but can appear as lights only by receiving relief from strong shadow. We often find them, in Paul Veronese and others, made to stand as darks, or to give objects an appearance of solidity without breaking up the general mass of light in the picture.

[*] A light figure may be strongly relieved even by a light background provided the colours are opposed to each other, thereby preserving the greatest breadth of light. The warm colour of flesh, for example, necessarily detaches itself from a cool ground. In such situations, we often find Rubens and all his pupils bring strong blue in contact with the head, a contrivance which gives it great value and relief, and a luminous effect.

[†] The picture "Jacob's Dream," by Rembrandt, in the Dulwich Gallery, gives an admirable illustration of the effect here alluded to. The angelic spirits, "ascending and descending," are sufficiently prominent, and yet have no distinct or positive contour, and are surrounded by such a dreamy stillness and ghostliness, that the imaginative spectator is impressed with their importance in the scene, and yet must draw upon the stores of his own invention to give them any form.

[‡] One of the many difficulties with which the artist has to contend, is to represent the rotundity of objects composed of strong local colour. In the earlier masters we find the figures possessing a flat, inlaid appearance, with the lights strongly charged with local colour. In the next advances of the Art, we find the light part of figures kept nearly white, though clothed in strong coloured draperies; which we even perceive in many of the pictures of Raffaelle, such as his Transfiguration, &c., till at length we find the strong colouring of Giorgione and the delicate light of Correggio, combined in the works of Titian, who has united the severity of the earliest masters with the softest effects of Nature. Correggio was the first who attended particularly to the influence of aerial perspective, and who preserved the breadth of light and shade undisturbed by colour. In this he has been followed by Rembrandt and Reynolds. His lights are much impasted with white, over which are laid colours of the most delicate nature, or semitransparent washings, which permit the ground to shine through, giving a luminous effect; or tints in which a considerable portion of white is mixed. He thus preserved the rotundity of his figures, while he filled his shadows with a juicy vehicle, in which transparent particles of rich

Repose.

(295.) That when such a balance is maintained between the light and shades and colours of a picture, as that it shall neither be feeble, (Art. 291,) nor spotty, (Art. 292,) nor insipid, (Art. 293,) but shall draw the attention of the spectator to its details, without any startling or too abrupt effect on the one hand; and on the other, without causing weariness, or any painful effort of attention, the result of such a balance is properly termed *repose*.* This term, however, is most usually applied to effects produced by breadth of shadow, as having less in them to excite or arrest the eye.

Warm and cold colours made to assist each other, and adapted to the character of a composition.

(296.) That the warm colours, (namely, yellow, orange, and red, see plate xi. fig. 5, 6, 7,) together with such compounds as incline decidedly towards them, arrest the eye by their exciting properties,* and like light upon dark, or dark upon light, (Art. 290, 294,) give prominency to objects. Also the union of warm colours is promoted by the introduction of a cold colour. Thus the whites, yellows, reds, and browns of a picture receive increased harmony by the presence of a blue.

(297.) That the cold colours (namely, violet or purple, blue and green, together with such compounds as have blue for their foundation) have a much less exciting influence upon the eye. They have the quality of making objects retire; and seem to produce a similar effect to that of middle tint upon half light, or of extreme dark upon half dark. (Art. 290, 298.) Cold colours, therefore, should perhaps predominate in compositions of a quiet, meditative character. Also the union between their cold tones is essentially promoted by introduction of a warm colour. Thus the whites, blues, greys, and greens of a landscape will be made to blend much more harmoniously by the presence of red, which derives at the same time from its isolated situation (Art. 305) a force and brilliancy approaching to harshness.

Borrowing his terms from Music, the Painter, when the prevailing tone of his picture is cold, pronounces it painted in a *cold key*, on the other hand, when the prevailing tone is warm, the picture is said to be in a *warm key*.

(298.) That pure and bright colours (plate xi. fig. 4) having greater force than when compounded, should occupy the chief points in a picture, and should be more or less employed as the composition is of a brisk, a quiet, or a mournful character. Colours composed of two primitives may be made to blend and soften by a small portion of the third primitive. Any colour may be tempered with white or with black. By means of these extremes (the observation is made by Mengs) may any colour in the hands of a judicious artist be reconciled and brought into harmony with another.†

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warm colour are floating, thereby leading the light into the darkest masses without its being reflected from their surface. This property of the illuminated parts of bodies to give back the light and the absorption of it in the shadow Correggio may have learned in studying his models by lamplight, as his breadth of light and shade leads us to suppose was his practice. Reynolds advises, for the sake of harmony, that the colours, however distinguished in the light, should be nearly the same in the shadows, and of

a simple unity of shade
As all were from one single palette spread.

"This, however, must be done with caution, as we find in Nature, and in the best colourists, exceptions in the shadows of many of the colours. For instance, in the shadows of red we find the local colour preserved more strongly than in the shadows of other colours: and white when warm in the light, is cool in the shadow. When the mass of shadow is warm, the introduction of some dark blue or cool black, will be of service to clear it up, and give it air; while the introduction of red will often focus the warm colours, and give them richness, together with more appearance of truth. I may also notice here that nothing gives a more natural look than to preserve in shadow the local colours of a shadowed object, provided they are not too light to disturb the breadth, for they give clearness and precision. They show, also, that particular relation which one colour bears to another, for colours in shadow have not the property of communicating their reflections to one another, whereas in the strong light the rays are refracted through the atmosphere from each colour tinging the whole with harmonious union. Distinctness of local colour and precision of outline are the peculiar character of objects placed out of the way of strong light. In sunshine the outline of objects enlightened is full and soft, surrounded by tones of an indistinct nature. In Rembrandt we find particular attention paid to the effects of light upon colour, effects which his rough manner of using the colours contributed not a little to give. Sir Joshua Reynolds seems to have constantly contemplated this bathing of his colour in the splendour of sunshine. If he has given us a translation of the works of Titian unimpaired, it is from his having made use of the Dutch version. That brilliancy of colour in the lights of his pictures, that mixed chaotic hue made use of to give it value; that diffusion, by the means of one colour carried into another—touching in his white with yellow tints, working in his yellow with red touches, and enclosing his red with black of a cool tone, so as to make even his shadows partake the influence of light—thereby preserving the greatest breadth of chiaroscuro, are the peculiar properties of Rembrandt. In Titian we have the white drapery more distant from the flesh tint than in Rembrandt and Reynolds, in whose pictures the luminous character of the flesh seems to show its influence upon the lights of the white drapery, as well as to tinge its grey shadows with a reflex of yellow. This extension of light, therefore, by means of colour is the mode of combining the powers of both, a mode founded in Nature, and adapted by the best colourists." See Burnet, *On Light and Shade*.

* Ostade's pictures have the peculiar property of looking well at a distance. They thus attract the spectator towards them. When we approach to take a nearer view, we observe that this effect is produced by their possessing a decided mass of light obtained by means of a light wall or sky, &c. His heads and hands form a number of luminous spots upon a mass of half tint, and are rendered of more value by the introduction of yellow and blue draperies. Such a system requires considerable management in order that these spots, to prevent confusion, may take agreeable and decided forms. Such a system, however, is the more easily pursued in Ostade's works, because he has seldom any particular story to interfere with the arrangement. In pictures upon a dark scale, (Art. 292, 294,) harshness arises commonly from the want of sufficient quantities of middle tint and half light. (Art. 290.) By this omission, the principal light is too much defined: the fault of Caravaggio.

* The Chevalier d'Azara, who edited the works of Mengs, adds a note at the commencement of the *Lexicai pratiche*, to state his (D'Azara's) opinion that the rays from dazzling objects give more than the ordinary impulse to the organs of vision, and therefore excite them too much, whereas rays of the opposite extreme, giving a less impulse than that to which the eye is habituated, cause too little action; and "thus both extremes" (like those of burning and freezing) "are disagreeable." Vide *Opere di Mengs*, Italian edition, vol. ii. p. 272.

† "White reduces the asperity (*asprezze*) of any colour till its tone assumes mildness and tenderness: black also removes harshness, but in a different manner, by smothering (*smorzando*) and obscuring it. Rembrandt, by means of shadows, shews how to reconcile the most incompatible of colours. He leaves only one spot of such colours in light; he separates some of them from the rest; and when obliged by the nature of his work to bring them together, he invents some artifice for enlightening the one, and enveloping the other in shade; since, if he had placed them in conjunction, he would, by the laws of chiaroscuro, have only represented light and shadow without colour. A method, the opposite of this, was that of Baroccio, who harmonized all his colours by the aid of white; reducing, indeed, their force, but bringing into concord their most discordant tones, so that (by this increased breadth of light) his picture was an example of chiaroscuro artfully composed, and having considerable brightness and prominency, (*molto rialzato e ben composto*.) Rembrandt," he adds, "seems to have viewed his subjects in some cavern which only one ray was permitted to penetrate: Baroccio, on the other hand, appears to have beheld his only in the air or among the clouds, where perpetual lights and reflexes left him scarcely any shadow. Rembrandt, of these two extremes, is preferable to Baroccio, since some architype of Rembrandt's works may be found in Nature, whereas those of Baroccio have place only in the imagination." In some of the designs of Rembrandt, observes

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(299.) That as in the case of light and shadow it becomes necessary, for avoiding flatness and insipidity, (Art. 293,) to have a focus of light, so with respect to colouring a focus of colour may, with similar good effect, be made by repeating, in a stronger tint, in a favourable position, and in a comparatively small compass, some prevailing hue. And as in the case of lights and darks, a small portion of each introduced into the other is sufficient to produce a harmonious union; (Art. 295;) so also in the balance of warm and cold colours a similar process is similarly advantageous. Harmony may be effected, and yet by the same means the greatest breadth (Art. 294) preserved.*

(300.) That not only colour acts thus powerfully upon tints of the same hue, but exerts its influence more or less, according to its brightness, upon the tones of every other hue.†

Colour as a shading material represents solidity.

(301.) That colours, besides their property of warmth or coldness, contribute more or less to the balance of light and shade in a picture. (Art. 284, No. 4, and Art. 299.) Thus a figure in red may serve the purpose of a half dark, (Art. 290,) while it serves likewise as a focus to the other reds of the picture. (Art. 294, last note.) The introduction, therefore, of any strong colour must be in subserviency to the balance of light and shade in a composition. If it destroys that balance it is introduced improperly. Mengs speaks of the colouring of light and shade, and means that every colour, besides its influence as giving warmth or coldness, has a duty also to perform in the shading of every picture, and holds a specific rank in the scale of lights and darks. Perhaps we might reverse the terms of Mengs, and make this property more intelligible by calling it the light and shade of colouring.*

Number of lights in a composition.

(302.) That in every picture there should be three conspicuous lights, differing from each other in power, as well as in size and form.† The distance between

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Mr. Burnet, (*On Light and Shade*, p. 16.) he seems to have allowed the entire half of his canvass for repose, and to have confined his composition with all its lights and darks, and colours, to the other half. Very little often serves to connect the two. The dark manner of Rembrandt has advantages over every other, if kept within due bounds, as it enables the Painter to give a rich tone to his colours without their appearing heavy, which more feeble backgrounds would not admit of, unless the colours are to stand as darks instead of lights; accordingly we find Titian, Tintoret, Georgione, Rembrandt, and our own Reynolds all swayed by the same opinion.

* Thus in a landscape, the blue of the sky may be advantageously repeated by a drapery of stronger blue made to appear among the warm brown shadows of a foreground. In like manner the glow of a morning or evening sky may be focussed by strong red drapery, placed in the neighbourhood of greys and greens. The works of Claude and of Cuyp present continual examples. The effect, too, of all strong colour is to make the weaker tints of the same or of a proximate hue retire. Thus is obtained an interval between the strength of the one, and the comparative faintness of the other, for expressing space or distance: and the spectator's imagination becomes impressed with the idea of *airiness* in a picture, and of ample room for whatever objects may be introduced.

"Titian often has his red placed near the centre of his picture, which gives it consequence, and he either throws it into much light, or keeps it flat, according as he wishes it to tell as a dark or light in his scale of chiaroscuro. Mengs supposes Titian to have used colours more or less retiring upon his figures according to their situation. Such is not, however, his principle; and strong colours are more often used by him to support his composition, without any reference to their being employed upon the most prominent points. From Raffaelle to Rubens we often find them introduced upon background figures, as darks in light pictures, and as lights in dark ones: sometimes carrying the eye to the point of attraction, sometimes for clearing up the shadows. We often find portions of deep lake dresses running into the dark masses of Tintoretto and P. Veronese; and we know the more a picture is made out by colour, the lighter the effect will be, and the nearer allied to the appearance of Nature in open daylight." Burnet, *Hints on Colour in Painting*, p. 26.

"In many pictures of the Dutch School we see a perfect harmony sustained between the hot and cold colours of a picture: we see the warm colour contained in the foreground, and strong darks wove into the masses of neutral tint in a multiplicity of ways. To focus the warm colour of the ground, we often find figures dressed in red, or we find withered leaves, bark of trees, pieces of brick, &c. made use of, and observe warm colour insinuating itself into the colder by a variety of channels. We perceive the cool tints of the sky and distance diffused by the grey colour of wood, stems of trees, grey road or water, taking the reflection of the sky. In many of the works of Wilson and Gainsborough we see the richest effects of colour produced by this mode of arrangement; using the middle ground as a ground of union between the warm and cold colours." *Ibid*. p. 16.

† For example, green is greener in the presence of red than of any other hue; and red redder in the presence of green than of any other. Cool tones may thus be said to give more value and greater warmth to warm tones by being placed beside them in a picture, and *vice versâ*. Indeed, all reflected lights are of a warmer colour when the light is cool, and therefore, in such cases give greater warmth to the shadows. But these reflexes being comparatively of a lesser degree of warmth when the light is warm, they require the presence of blue or of some object of a cold colour introduced to give them value. (Art. 299.) It is also observable that if the strongest or deepest tints of colour be placed in the dark portion or side (Art. 294) of a picture, the shadows surrounding them will prevent their strength from wearing a dull, heavy aspect. They will appear under the influence of light, an appearance not to be obtained for them in any other part of the composition. Further it is to be remarked, that according as the shadow is increased in warmth, the light partakes a portion of its warm influence; thus in Rembrandt, where the dark masses contain burnt sienna or lake, the blues and greys receive a tinge of yellow; while in Teniers, whose shades are of a cooler brown, the blues and greys retain greater freshness.

In arranging the general tone of a picture, and the balance between warm and cold colours, it is not necessary for the light always to be of a warm tone. But when the light is cool it is important that the shadows should receive warmth either by the introduction of objects with warm local colour, and therefore, warm reflexes: or by such contrivances as are to be found in the Dutch School, in Rembrandt for example, who having admitted light mixed with cool pearly tints into an apartment, has been careful to illuminate the shadow by a fire purposely introduced in an opposite corner of his picture.

"At sunrise," observes Mr. Burnet, "when the sun's disk is visible by reason of the density of the atmosphere, we observe the yellow light round him tempered and softened down with delicate grey: which tint being also diffused over the local colours of the landscape gives truth and harmony. In Claude we perceive the same breadth, delicacy, and softness. In the evening when the atmosphere is less dense, we find the colour of the light more brilliant and less interrupted, tinging with the same hue every object placed within its influence. This we find also in Cuyp and others, who have painted landscapes under the same circumstances. Here is a good foundation to commence upon, and we can only produce an agreeable and natural appearance by employing such means. White and black can be reconciled only by the interposition of grey, and red and blue by the presence of a third colour, combining the properties of hot and cold. Light will be more easily spread by the lesser lights partaking of the same hue as the principal, and shadow more easily diffused by the same means. We thus preserve the breadth observable in Nature. But as this would in many cases produce monotony, we have a third quality to consult, namely, variety, which in Nature being endless, we have an inexhaustible source to draw upon. And very few colours are necessary to produce this multiplicity of changes. In the employment of them, however, we must always bear in mind the necessity of preserving the breadth of light and shade, (Art. 294,) and the balance and union of hot and cold colours." (Art. 306.)

* It was the method of Correggio, as was observed, to preserve his light and shade undisturbed by colour, and to use colour for heightening not impeding chiaroscuro; strong colour holds the place of middle tint, and is neither seen in the high light nor in the deep shade. If used as an intermediate link it will unite both, preserving at the same time a greater consequence and force. Whether it is to be warm or cold must depend upon the colour of the principal light of which it is to be considered an extension. See Note (E.)

† "Though to the principal group," says Reynolds, "a second

these lights may be varied at pleasure,* but they should generally be arranged in an irregular kind of triangle.†

Grouping.

(303.) That in a group, or assemblage of several figures, an odd number is preferred, as three, five, seven, &c. Among the even numbers, Mengs chooses the number two, and observes that two figures of unequal sizes are the least disagreeable to the eye: but that couples are always ungraceful. A group, he adds, looks best in the form of a pyramid, which for better relievo should assume at its base a somewhat rounded form. Its large masses should be disposed in the centre of the group, while its smaller members should be left as stragglers round its edge to give it lightness. If there are several groups or *pyramids*, he prefers for them also an odd number. He desires the principal figure to take his stand in the middle group. But if several figures of equal importance to the story occur, let them, he says, be all placed near the centre of the work, and in the middle ground, in order that by means of light and shadow they may receive relief and consequence from objects surrounding them. In general, he adds, let the group form itself in a semicircle, either concave or convex, in order to give its central and principal figure every advantage of relievo.*

Of Composition.

Unity and variety to be preserved in the colours of a group.

(304.) That when numerous figures are introduced into a composition, there must be great variety of colour. Confusion may be prevented and unity preserved by repeating the same colour in different parts of the work. These colours, however, in their passage from high lights into deep shadow must have great varieties both in tint and tone, and thus opportunity is afforded to the ingenious composer for a chain of harmonious intervals.†

Two requisites for every object on canvass.

1. Its distinctness as an object separated from every other.

(305.) That in order to confer distinction upon an object it must by some means be made to stand apart, and in a state of isolation, if we may so express ourselves, with regard to the objects which surround it in the picture. This is effected by *contrast*, which we may define to be an abrupt transition from one kind of outline to another totally different, or from bright light to deep shadow: or from one interval or tint or tone of colour to its opposite. Thus in the case of outline, one sitting figure being introduced into a group of standing figures, becomes remarkable, or *vice versâ;* or a figure is made conspicuous by an horizon at or near its feet; or in a group of figures who all, with the exception of one only, look steadfastly in the same direction, that one figure turning in an opposite direction becomes distinguished. Such is the form of the Saviour turning to his disciples in the "Pasce oves" of Raffaelle. The figure, too, of St. Peter kneeling, while it distinguishes that Apostle from his brethren, contributes to elevate the figure of Christ, and confer appropriate dignity. (Art. *279.*)

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or third be added, and a second or third mass of light, care must be taken that these subordinate actions and lights, neither each in particular nor all together come into any degree of competition with the principal: they should merely make a part of that whole which would be imperfect without them." See *4th Discourse.*

* The relative position of the lights and darks in a picture determine its character. 1. If the extreme light and extreme dark be placed at opposite corners of the picture, with a diagonal line between them, this is an opportunity for the greatest breadth. 2. If the principal light be in the centre of the picture, it will have great brilliancy when in contact with a small portion of dark; but in this arrangement there is less opportunity than when the light is at one side for a large breadth of shadow. 3. If a mass or focus of shadow be placed in the centre, and light be carried round it by means (in landscape, for example) of sky, water, or light foreground, the picture is a converse of the preceding, with less opportunity for breadth of light, but with strong effect for the central mass of shadow. 4. If a mass of shadow be carried across the middle of a picture, opportunity for great breadth and for repose is afforded. To these observations it may be added, that whenever light is repeated for a union of the two sides of a picture, it should be a repetition of the same colour. Thus Cuyp, whose principal light is often yellow, carries it into the dark part of the picture by means of yellow drapery, a cow, a sheep, or a few touches to represent bright golden reflexes from polished objects.

† The largest or principal light in which the principal figure or subject must appear, should generally occupy about an eighth or even a fourth part of the picture, and should be situated not far from the centre of the canvass. When a multitude of small objects are introduced into a picture, or when the general arrangement consists of many figures, breadth of light and shade is impossible unless many of them are united together of the same strength, so as to form a mass of light or of dark. Salvator Rosa and Wouvermans adopted for this purpose the artifice of introducing two or three white horses, and Weeninx a swan. Nature, however, abounds with much more probable expedients.

The second or third light, occupying another eighth of the surface, should be bestowed upon the figures or objects of secondary importance; contributing nevertheless to the primary object of the picture. Accessory or subordinate objects are to be rendered visible by reflexion only. "The same rules," says Sir Joshua Reynolds, (in his Notes upon Du Fresnoy,) "which have been given in regard to the regulation of groups of figures, must be observed in regard to the grouping of lights; that there shall be a superiority of one over the rest, that they shall be separated and varied in their shapes, and that there should be at least three lights. The secondary lights ought for the sake of harmony and union to be of nearly equal brightness, though not of equal magnitude with the principal." Again he says, "We will suppose Titian's bunch of grapes placed so as to receive a broad light and shadow; here though each individual grape on the light side of the bunch has its light and shadow and reflection, yet altogether they make but one broad mass of light; the slightest sketch, therefore, will have a better effect where this breadth is preserved, than the most laborious finishing where this breadth is lost or neglected."

"From the time of Cimabue," says Mr. Craig, "to that of the great Raffaelle, the light and shadow of pictures was very little studied. The pictures of that period, however great in invention, composition, and drawing, were in their general appearance flat and uninteresting. The first principle which seems to have been perceived by the early Italian masters, was that a light is made lighter by being opposed to a dark; and for some time we find in their works a constant association of some portion of dark with every little bit of light, whatever be its place in the picture. Giorgione was perhaps the first who endeavoured to give simplicity to his pictures by the introduction of broad shadows and contracted lights. Some of his portraits are from this circumstance objects of the most gratifying contemplation. Titian, who imitated his fellow-student Giorgione, caught an idea of breadth from seeing his works, though he appears not to have understood the principle which produced them. The pictures of Titian have therefore great breadth of light and dark; but it is often very abrupt, and often scattered at random. Correggio was unquestionably the first Painter who made the success of his works to depend on light and shadow." *Lectures*, p. 154.

* Of a concave group (that is, having the concave of the semicircle towards the spectator) examples will be found in such pictures as West's "Death of Wolfe," or the lower group of "The Transfiguration" by Raffaelle. Of a convex group an example is seen in the assemblage of the Apostles at the upper part of the Cartoon of "Ananias." As light and shade determine the concavities or convexities of objects, without light and shade, the most intelligent outline would be but as a map or flat surface. If, for example, we take a bowl or cup, and examine the influence of light and shade upon it, we find in the shading of Nature those principles which artists have applied to many purposes in Painting. We perceive the near edge strongly defined by the light side coming in contact with the shadow, which becomes darker as it descends into the cup. We have also the dark side brought firmly off the light, thus exhibiting to us the simplest and most effective means of giving a true representation of its character.

† "A pale yellow," says Mr. Burnet, "may terminate in a deep brown, yet a chain of communication be kept up; or a pure white may find repose and union in a pure black; a bright red vibrate (to use a term in Music) through a chord terminating in the gentlest echo of such a colour," &c.

The same principle of isolation may be pursued in the use of light and shadow.[*] The focus of light on any leading or primary object,[†] creates a contrast in proportion to the darkness of the adjacent objects. (Art. 283.)

Again, this power of relief by contrast may be obtained through the assistance of the local colours of objects. (Art. 284, No. 2 and 4.)

And further, an object may be isolated, and drawn out from others by the contrast of its warm colour with the coldness of those other surrounding objects. (Art. 284, No. 5. Also 296, 297, 299.) Thus the distance of a landscape is often of use in giving prominency to a portrait while a low horizon elevates and gives dignity to the figure. Also, when the general tone of a picture is warm with brownish shadows, blue drapery and cool black will have greater force. Of this, Paul Veronese and Rubens afford many examples. Claude has often profited by this opposition of colour. In light pictures, (Art. 294,) this opposition is extremely valuable to the artist, who may thus give relief and distinctness without injuring his breadth of light. He may place blues upon a warm ground, reds upon a cool ground, bright yellows upon cool grey, &c.[‡]

2. Its consistency as harmonizing with the whole picture.

(306.) That a painted object in its opposition, for the sake of relief, to the other parts of a picture, although it is thus contrasted with the rest in some respects, must harmonize with them in others. As any object is rendered more conspicuous by contrast with its opposite, so it is rendered less and less prominent at every step of their near approach to similarity. This agreement may, like the opposition above mentioned, (Art. 305,) be effected variously. In outline, a repetition of the same lines in features, posture, or action, (Art. 264, 279,) conduces to a balance between the different members of a composition. Thus the regularity in the cartoon of "Ananias and Sapphira" is remarkable. On each side of the semicircle (Art. 303) in the lower group are several figures, no one of whom, except Ananias and Sapphira, performs an action that is not repeated, while the Apostles being elevated on a higher position, maintain, although diminished by distance, a commanding aspect in the picture; and with all of them likewise the lines of drapery and contour are repeated. An agreeable method also of doubling the lines in landscape is often produced, as in the works of Cuyp, Rubens, and Teniers, by placing the foreground figures, as well as the middle ground, the distance and the clouds all on one side of the composition in such a manner that each in relieving the other shall in some degree repeat its contour. The strong light and darks of figures in a landscape so composed tell with great force against a background of houses, trees, mountains, &c. and these again are prevented from being harsh, sharp, and cutting by mixing their edges with the clouds.[*]

Repetition, in chiaroscuro and in colour, tends likewise to the same effect with repetition of lines. A quantity of light taken from the bright side of a picture, and exchanged for a portion of dark from the side opposite conduces to a balance.[†] And in a similar manner, a

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[*] Some artists maintain, and justly, that every *light*, however small, ought to have a focus, or one part lighter than another. As we find this to be a general law in Nature, there can be no safer ground to go upon. For the same reason we ought to have one portion of a *dark* more decided than the rest. If these two extremes are brought in contact, we make them assist each other, one becoming brighter and the other darker from the effect of contrast. If they are placed at the opposite sides of the picture, we have greater breadth and a more equal balance. (Art. 294, 295.) Let us take some head by Rembrandt for an example: we shall find the principal light or focus in the upper part of the face which he often surrounds, to render it more luminous, with a black bonnet or hat, and even this is kept of a cold tone that it may give more value to the complexion. The light is then allowed to spread downwards, and be repeated on the figure. He thus produces union, and gives his light the appearance of diffusing rays of the same hue with itself. If we follow him in the conduct of some of his larger compositions, we find the same principle adopted, whether they consist of many figures, such as the Hundred Guilder-print, or of few, as the small Nativity in the National Gallery; thus rendering the most complicated compositions subservient to the simplest principles of light and shade. A few experiments on a ground of middle tint with a pencil filled with white, and another dipped in black, will give the student an insight into all the changes capable of being produced on this principle. Sir Joshua informs us that when at Venice, he took a blank leaf of his pocket-book, and darkened it in the same gradation of light and shade as each picture before him, leaving the white paper untouched to represent light. After a few experiments with different blank leaves on different pictures, he found every paper blotted nearly alike. Their general practice appeared to be, to allow not above a quarter of the picture for the light, including in this both the principal and secondary lights; another quarter to be as dark as possible, and the remaining half kept in mezzotint or half shadow. Rubens appears to admit rather more light than a quarter; and Rembrandt much less, scarce an eighth.

[†] Rembrandt, in his early practice of art, attempted to represent flame by darkening every other part of the picture, but by this means his flame became the only distinguished actor on the scene, while living agents were but secondarily prominent. His next expedient, therefore, was, to conceal the source of light, and to throw its rays upon his principal personages, according to their importance in the picture. Accordingly, his picture of Christ raising the daughter of Jairus is a sublime example of this effect. In this composition, Rembrandt, by throwing his light upon a light object, has the advantage of making reflexes from it upon other adjacent objects. His shadows, caused by such reflexes, are sometimes, as in Nature, strongly defined; and for the sake of these shadows, we observe him often introducing such objects as will serve the purpose.

[‡] Rembrandt, when his light is cool, makes his shadows warmer the darker they become. Rubens, whose style was grounded on the Venetian school, seems guided by the same opinion. "Begin," says Rubens, "by painting in your shadows lightly, taking care that no white is suffered to glide into them; it is the poison of a picture, except in the lights; if ever your shadows are corrupted by the introduction of this baneful colour, your colours will no longer be warm and transparent, but heavy and leady." Opie thus describes, in his Lectures, Correggio's management of chiaroscuro. "By classing his colours, and judiciously dividing them into few and large masses of bright and obscure, gently rounding off his light, and passing, by almost imperceptible degrees, through pellucid demitints and warm reflexions, into broad, deep, and transparent shade, he artfully connected the fiercest extremes of light and shadow, harmonized the most intense opposition of colours, and combined the greatest possible effect" (of contrast) "with the sweetest and softest repose imaginable."

[*] "Mark in strongly," says a judicious artist, "those points in the ground, which of necessity must be introduced from natural circumstances, at the same time contriving your group, so that those points become of the greatest consequence to the composition." A richness of effect is produced either by such a combination of light and shade as will give the appearance of doubling to the outline; or by relieving the outline by a ground possessed of a variety of strengths. A small portion of any group or figure, coming firmly and sharply off its ground, is quite sufficient to give the appearance of natural solidity to the whole.

[†] The arrangement of light and shade as relates to the *whole* of picture ought never to be absent from the student's mind. "If a diagonal line," says Mr. Burnet, "be drawn through the picture," (to divide a breadth of light from a breadth of dark,) (Art. 294,) "and a balance or union between the two sides be wished, there is no other way but by borrowing a portion of the one, and exchanging it for a portion of its opposite. Not only may this practice be made use of for the harmony of the whole, but the light and the shade will be thus rendered more intense by the force of opposition. Whether the dark which is carried to the light side be very small or

balance of warm and cold colouring may be effected.* As therefore contrast or isolation is brought about by abruptness, (Art. 306,) not only in placing a focus of extreme light near to extreme dark, but also in placing the repetition or focus of a cold colour among warm tones, or of a warm tone among the cold colours of a picture, so does this very act of repetition generate at the same time a bond of union and a balance of power throughout a composition between the properties of light and warmth on the one hand, opposed to those of darkness and coldness on the other.†

Again, as the opposite to abruptness is insensible gradation, so when two opposing tones or tints have a harsh effect in juxtaposition, their harshness may be reduced by intermediate tones or tints, (Art. 284, No. 4, 5,) so as to produce a gradual and delicate succession of harmonious intervals. (Art. 298.) Or, between two colours of which the tones antagonize; between, for example, two primitives, as red and yellow, the disagreement may be in some measure abated by making each of nearly the same tint or degree of strength. Thus, the blue, No. 13, (plate xi. fig. 5,) will be found to have less hostility to yellow, No. 7, if they be both taken from the same tint, that is both taken from the circumference of the same circle, and have both of them two, or four, or six, &c. degrees of strength.

Lastly, any excess (in form, in light and shade, or in colouring) which has been unduly given to one object over another may be reduced by the introduction of a third object, which, acting as a foil to both, and showing a much greater excess, makes the difference between the two former objects less open to observation. Thus in outline, the difference between any curve or straight line, or between any two curves, may be made scarcely perceivable by introducing a third line which has a degree of curvature considerably greater. Also a line very slightly curved may appear formal and lifeless, (Art. 264,) till a line exactly straight is placed near it. Again, in chiaroscuro, the interval between a light and a shadow or between any two shadows may be made to appear considerably smaller by the juxtaposition of a third shadow of extreme and intense darkness.‡ Also, in colouring, the interval between any two tints is apparently reduced, and the gradation consequently made more soft and more harmonious by a third tint in contact with them, which differs more in tone from either than they do from each other.* Correggio and Rembrandt frequently relieved the dark side of their figures by a still darker background.

(307.) That respecting the materials which are to be put into operation for Painting, the artist can acquire little from any written description, but must perfectly acquaint himself by practice alone with the peculiarities (as well defects as excellences) of whatever vehicle he uses. We shall, therefore, only here remark, in conclusion, that the foregoing rules apply equally to all the different vehicles and materials adopted in this Art: whether *oil colours*, which from their great power of expressing with perfect clearness the deepest gradations of shadow, have been generally held in highest estimation; or *water-colours*, which in this Country have been raised to almost equal power, and brought to a perfection never before known; or, thirdly, *crayon* Painting by means of coloured chalks; or, fourthly, *fresco* Painting, (so called from being performed on *fresh* plaster,) which from its unrivalled brilliancy of effect, and its connection with Architecture, was the favourite of the early Schools in Italy. To these several vehicles may be added *Mosaic*, or the beautiful as well as durable representation of Nature by small pieces of variously coloured marble; *inlaying*, or a somewhat similar operation in wood; *enamel*, or the process, on copper or gold, of Painting with mineral colours dried and melted in by fire; together with contrivances by means of wax, called *encaustic* Painting; or by *staining glass*, an Art allied to enamelling; not to mention the successful competition of the loom with the easel, in the still more ancient devices of *tapestry* and embroidery. These several materials for pictorial effect may be compared to the several instruments used in Music, all vibrating in separate ways, under distinct and separate forms, and by impulses suited to each; all of them diversified in their modes of operation, but all subservient to one system, and all combining to answer by different means the peculiar ends and purposes of the Art which emp:oys them.

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very large, or *vice versâ*, we have here the groundwork of some of the most powerful and most natural effects in Painting." *On Light and Shade*, p. 6.

* "If a diagonal line," says the same Writer, "be drawn across the picture," (he alludes to the Bacchus and Ariadne of Titian,) "we find it composed of a mass of hot and a mass of cold colour, laid out upon the broadest scale, and aiding each other by the opposition." The greatest breadth, indeed, is (Art. 294) to be preserved in colouring by a division of the picture into hot and cold colours. The contrast of warm hues with cold increases their richness, the aerial perspective is improved, and the foreground figures receive solidity without the help of black shadows. "That a picture," observes the author just quoted, "should consist of hot and cold colours, is as indispensable, as that it should have light and shade. Which shall form the light, and which the shade, is entirely at the option of the artist. It is, however, necessary that these colours should occupy separate places in the balance of chiaroscuro, and that by any exchange of portions from the side warmth into that of cold, both extremes of the work may be harmoniously united.

† It frequently happens, that only one light appears in a single head. This must be made to harmonize with the shadow either in the background, or in the dress. Rembrandt, for this purpose, painted the light of the dress the same colour as the shadowed side of the face.

‡ The dark forming the greatest mass of shadow in a picture is often, before being brought into contact with extreme light, increased and collected to a point by some object whose local colour conduces to that purpose. Thus the black portion of a female's dress (in a Painting by Metzu, as described by Mr. Burnet) is brought, at its darkest part, in contact with the brightest portion of her white dress. This gives air to the deepest shades of the background, as well as greater firmness to the object so relieved.

* Any colour may in its tone so nearly resemble a primitive, as to be mistaken for it, until the introduction or juxtaposition of that primitive. Thus a green may be so nearly blue as to appear so till blue is present; or so nearly yellow, as to be taken for that primitive till yellow is present. As the repetition of a colour in various parts of a picture diffuses the light, and gives breadth of effect, so also repetition destroys proportionally, at the same time, the power of that repeated hue to give singularity and prominency to the object which it colours. A colour, therefore, will be often seen, in the best Masters, not only *single*, but surrounded by others totally different in tone, in order to increase its value. This peculiarity of colour is of the utmost use as to bringing out such points as the artist wishes to draw attention to. Not only does he thus obtain for that one colour the greatest force that his palette can give it, but he often brings all the rest into better agreement with one another.

NOTES ON PAINTING.

Note (A.)

The principles for drawing the boundaries of the shadow of any surface may be contained in the three problems which we here subjoin, and of which the mathematical reader will find the elements very succinctly stated in the fourth section of Creswell's Perspective. We will endeavour to state them in the most popular terms we can devise. Some previous definitions, however, may be necessary.

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Def. 1. Right lines drawn from a luminous point to any point in the illumined object are called lines of rays, and a plane containing any two such lines is called a plane of rays.

2. Rays that come from self-luminous bodies (Optics, Art. 4) upon other bodies non-luminous, we term primitive (or direct) rays. (Optics, Art. 54.)

3. Rays from bodies not self-luminous, but that have received primitive rays, are called derivative, or borrowed rays, or reflexes. (See Da Vinci, *Trattato della Pittura*, cap. 75—87.)

4. An infinite multitude of rays (borrowed or primitive) from any luminous body, being intercepted in their course by some opaque body; a certain number will be either absorbed or reflected. Between this intercepted number and the remaining unimpeded rays will be the boundary between light and shadow, which we will term the limiting surface, or column of shadow.

5. Direct rays from the sun or moon, are termed parallel rays, and will be represented by parallel lines.

6. Direct rays from small self-luminous bodies, sufficiently near to the object which they illumine, are termed diverging rays, and will be represented by right lines *diversely* spreading or diverging from the luminous point. (Optics, Art. 136.)

7. Where two or more luminous bodies have their rays intercepted by the same opaque body, the respective limiting surfaces or columns of shadow will intersect each other. The space included between the planes or surfaces of intersection is styled *dark* shadow. The remainder, from its lesser degree of intensity, is called *penumbra*, or *half* shadow. (Optics, Art. 34—36. Da Vinci, cap. 26.) Thus if we suppose a strong light to proceed from two bright clouds at B and D, (plate xii. fig. 1,) in front of the spectator, and suppose also through another bright cloud the sun near the horizon over the spectator's left shoulder, with its rays vanishing at V, there will be three shadows, *viz.* the shadow *a s p o n i*, caused by the interception of the sun's light; the shadow *e l m r b c;* and the shadow *e u t w q c*, caused by the interception of light from D and B. Where any two of these columns of shadow intersect each other, there will be a deeper shade in proportion to the brightness of each intercepted light. And where all three of them intersect, as in the area *a b c*, the shadow will be darkest. But this kind of effect is seldom so distinguishable out of doors. It is most visible, and most common in interior, or in in-door subjects, where the innumerable changes and modifications of window-light, candle-light, lamp-light, and fire-light, with their reflexes, cause inexhaustible varieties in the position and intensity, as well as colour of shadows.

8. If from any given point a perpendicular line be drawn to any plane, the point of contact where the perpendicular meets the plane is called the *seat* of the given point. Thus the seat of a candle on a wall or table is found in the point of contact, where a perpendicular from the centre of the light meets the wall or table. Also, the seat of any point in an object casting a shadow is found on the plane which receives the shadow, at the end of a perpendicular line from that point. For example, the point S^2, (plate x. fig. 3,) at the extremity of the perpendicular L S^2 to the plane *r w*, is the seat of the point L, as S is the seat of the same point L on the horizontal ground or plane S G F. So also S (fig. 4) is the seat of the light on the horizontal plane or ground; *a* the seat of *b ; d* the seat of *o ;* and *e* the seat of *o*. Again, the point *p* (plate xii. fig. 5) is the seat of the plumb line, and the point *a*, where the representation of a perpendicular meets a plane, is the seat on that plane of the point *b*, or of any other point in the direction of *a b*, produced to any length. Remark also A (plate xii. fig. 1) the seat of T.

9. A plane perpendicular to the horizon, and which in its vanishing line contains the vanishing point of the sun's rays, is called the *plane of altitude*. Thus the plane E A T (plate xii. fig. 1) is a plane of altitude vanishing in D O, which contains the vanishing point D of the ray E T, and its parallels. Thus also the plane I A T is a plane of altitude vanishing in B R where B is the vanishing point of the ray I T. In these examples, the sun's place is at B and D in front of the spectator. Again, U A T is a plane of altitude vanishing in M H, which contains M, the vanishing point of the ray T U, which comes from behind the spectator. Also, A T C is a plane of altitude vanishing in V L, which contains V, the vanishing point of the ray T C. Observe that T E A, T I A, T U A, and T C A, represent the respective angles of the sun's altitude.

But the plane of altitude has no vanishing line when the sun is in the plane of the picture, and has, consequently, his rays all parallel to that plane, and without any vanishing point. (Art. 36.) In this case, any plane parallel to the plane of the picture will be a plane of altitude. Thus the angle L T A, being the angle (plate xii. fig. 4) of the sun's altitude, the plane A L T is a plane of altitude, since it contains the ray L T, and as many parallels to L T as can be drawn crossing T A and L A.

10. The point where the vanishing line of the plane of altitude cuts the horizontal line is called the vanishing point of *horizontal* intersection. Thus the points H, R, O, and L, (plate xii. fig. 1,) the points *c*, *a*, and *b*, (fig. 2,) and the point L, (fig. 5,) are the vanishing points of the intersection of the plane of altitude with the plane of the horizon. (Art. 145, 189.)

11. The point where the vanishing line of the plane of altitude is intersected by the vanishing line of any plane containing any line or lines of solar rays, is called the vanishing point of *altitudinal* intersection. This point is, in fact, the vanishing point of the sun's rays. Through this point must pass the vanishing line of whatever plane contains lines of solar or lunar rays. For example, the points B, D, M, and V, (plate xii. fig. 1,) and the points M, N, O, P, Q, and R, (fig 2,) and the point V, (fig. 5,) are vanishing points of altitudinal intersection. And if in the plane D *l m*, (fig. 1,) containing the rays D *l* and D *m*, the line *m l* be prolonged till it meets at its vanishing point P, the vanishing line H L of its plane; next, if P D be joined, the line P D will be the vanishing line of the plane D L N, and must pass through D. In the same manner, *m r* may be prolonged to show the vanishing line of the plane *m* D *r*, and *r b* to show the vanishing line of *r* D *b*, &c.

Prob. I.

Problem I. *To find on any plane receiving a shadow the seat* (Def. 8) *of any given point situated out of that plane.*

The given point must be considered as belonging to some plane, as L S *v* S^2, (plate x. fig. 3,) making an angle with the given plane.

1. If the angle so made be a right angle, let the given plane be S *v* G F, or *r v x w*, both perpendicular to the plane L S *v* S^2.

First, find the line of intersection, as *v* S, or *v* S^2, (Art. 141, 187,) which the plane containing the given point L makes with the plane receiving the shadow. To that intersection draw from L (the given point) a perpendicular L S, or L S^2. The extremity S of that perpendicular will be the seat of L on the plane S *v* G F; and S^2 (the extremity of the perpendicular L S^2) the seat of L on the plain *r v x w*. In the same manner is found *t*, the seat of a given point *g* that belongs to the plane *g o m t*, making right angles with *r v x w ;* also (on the plane S *v* G F) *n*, the seat of *e* or *f ; p*, the seat of *d* or *c ; x*, the seat of *a ;* and *o*, the seat of *h* or *g*.

When these two planes making right angles with each other are *inclined* to the picture, as the plane *c a d e*, (plate xii. fig. 3,) at right angles with the plane *a* I *o b*, (supposed to receive the shadow,) their vanishing lines must be found, in order to determine H the vanishing point of their intersection *a b*. (Art. 145.) Then find the vanishing point of all perpendiculars (Art. 196) to the plane (here supposed to be *c a d e*) receiving the shadow. If that vanishing point be W, and L be the point given, a line from L to W will cut the intersection *b* H in *b*, the required seat of L; in the same manner as *b a* (fig. 5) cuts the intersection *c a*, and determines *a* for the seat of *b* on the plane receiving its shadow.

2. But if the angle made by the two planes with each other be not a right angle; let the given point be O (fig. 3) in the plane *a* I O *b*. In this case the intersections of both planes with the plane of measure (Art. 145, 146, 182) must be found; *viz.* O D, (which must be drawn through the given point O,) the intersection of the plane *a* I O *b*, and S M, (in the plane *c a d e*,) the intersection of the plane of measure with *c a d e*. Find W, the vanishing point of all perpendiculars, (Art. 196,) to the plane *c a d e*. Join O W. The point *x*, where this representation of the perpendicular cuts S M, is the required seat of O upon the plane *c a d e*. In the same manner *z* will be found on the same plane to be the seat of a point K in the plane K *a*.

Prob. II.

Problem II. *Given the representation of any finite straight line, to represent its shadow caused by rays diverging* (Def. 6) *from a given luminous point.*

Find the seat (Def. 8, and Prob. I.) of the light and the seat of the points at each extremity of the given straight line. Supposing the given line to be *a c*, (plate x. fig. 3,) the seat of *a* will be *z*, and the seat of *c* will be *p*. Then connect by other straight lines the seat S of the light with the seats *z* and *p* of the two extremities of the given straight line. Prolong these two connecting lines S *z* and S *p* till they meet at A and C the two rays L *a* A and L *c* C, drawn from the light through the two extremities *a* and *c* of the given straight line *a c*. The points A and C of this meeting or intersection will represent the shadows of those extremities, and a straight line A C between them will represent the shadow of the given line *a c*.

In the same manner we find G^2 the shadow of the point *g* cast on the plane *r v x w*, having first determined the seats S^2 and *t* (Prob. I.) on that plane. The line $S^2 G^2$, intersected by the ray L G, gives the shadow G^2 of *g*. Thus also the respective shadows of *e*, *f*, and *h*, as well as of *b* and *d*, are found to be E, F, and H, B and D. So likewise the rays L *h*, (fig. 4,) L *g*, and L *f*, determine the respective shadows of *b*, *c*, and *o*, by the prolongation of S *a*, S *d*, and S *e*, to *h*, *g*, and *f*.

Cor. 1. To determine any shadow intercepted by any opaque surface, find in all cases the several points where the respective rays from the primitive or reflected light meet the intercepting surface. Thus, as we have seen, at the point G^2 the ray L G is intercepted by the plane *r v x w*. And in a similar manner, the circular rim of the candlestick (fig. 4) may have its shadow determined on the cylindrical surface of the pillar, as well as on the book *b c d a*. Let a line through S, parallel to the vanishing line of its plane, (Art. 21, 64,) be drawn, and another parallel line for a diameter of the rim. Rays L *v* and L *w* drawn from L through the extremities of this diameter will determine *v w*, that of the shadow on the plane beneath. Next, (taking C for the centre of the picture,) complete the representation of the circle round S. (Art. 178—181.) Or, if the rim be of any other form, find the seats round S of the most remarkable points, and then the shadows, according to the process above detailed. Any number of radii from S, as S *x* and S *r*, will cut the circumference of the pillar, as at *m* and *u*. Draw through *m* and *u* lines parallel to the axis of the cylinder. These lines will cut the rays L *x* and L *r* in the points *n* and *t*. And in the same manner may be found any number of points required for completing the shadow on the cylindrical surface. The same process is applicable to a concave or interior surface of a cylinder, as also to the plane surface of the book *b c d*.

Cor. 2. Observe that the same methods are available for determining and circumscribing any portion of light, as we have adopted for portions of shadow. If, instead of the rim of the candlestick, a round hole in some opaque plane parallel to the plane at S were placed under the light; the same arrangement of lines would give the delineation of a circular illuminated portion of the plane below, and of its interception on the pillar, &c. So on the other hand, the four-sided figure *c b d a* (fig. 3) might be an opaque surface, and then its shadow would be C B D A.

Prob. III.

PROBLEM III. *Given the sun's altitude and the angle, if any, made by the plane of altitude* (Def. 9) *with the perspective plane to represent the shadow of any given point of which the seat* (Def. 8, and Prob. I.) *has been determined, or the shadow of any line of which the vanishing point is known.*

Our expression "if any," alludes to the sun's rays when parallel to the picture, in which case the plane of altitude can have no vanishing line. (Art. 67.) The last problem referred especially to divergent rays. (Def. 6.) The present refers only to shadows caused by the interception of parallel rays. A few previous observations may assist the learner.

Obs. 1. That the rays of the sun, on account of their distance, are reckoned as being parallel to each other. Let the reader, however, consult OPTICS, p. 415. sec. 39—43. for a general law. If a light be smaller than the enlightened object, the shadow diverges; if equal to it, the shadow will be of the same magnitude; if larger, the shadow will be smaller and less diffused.

Obs. 2. That if any original straight line (Art. 16) be parallel in sunlight to the plane which receives its shadow, the original shadow of that line upon the plane will be parallel to the line itself. Consequently, the representation of the shadow of that line will pass through the vanishing point of the original line. Thus, R K and T P (plate xii. fig. 4) being parallel to the plane H *w c*, the shadows *h k* and *s p* will be represented parallel to R K and T P. And thus *g f* (fig. 1) being parallel to the ground plane, (Art. 41, and note to Art. 17,) the shadow *w q* of *g f* will vanish with *g f* in the same point B. (Art. 76.) Also *e d* (fig. 5) will be parallel to E D.

Obs. 3. That if the shadow of a body in sunshine be received on a plane inclined to the ground plane, or be received on any surface whatever, the column of air darkened by the obstructing body (Def. 4) must first be determined. After this, the intersection of the representation of the inclined plane or other surface with the column will represent the boundaries of the shadow.

Obs. 4. That a shadow cast on a plane perpendicular to the sun's rays is composed of the seats on that plane (Def. 8) of all the points in the body or object which casts the shadow.

Thus if L A (fig. 4) be the direction of the sun's rays perpendicular to a plane containing T A, and the shadow of T L be required, T A will be that shadow, composed of all the seats of all the points in T L. So also, if T A (fig. 1) be the direction of the solar beams; E A will be the shadow of E T; U A of U T; I A of I T; and C A of C T; and the house at O will have no shadow.

Obs. 5. That shadows cast on a plane to which the rays are parallel will be interminable. In such a case the lines of direction for the shadows have, when not parallel to the picture, the same vanishing point with the rays. (Art. 76.)

Obs. 6. That in all shadows two things are to be considered: the *direction* of the shadow, and its *length*. The length is determined by lines of rays drawn to meet the lines of direction. Thus, if A T (fig. 4) be the line of direction for the shadow of A L, a ray L T through L will give the shadow of L at T. Or if A E, (fig. 1,) A U, A C, or A I, be the line of direction, the shadow of A T, the ray T E, or T U, or T C, or T I, may determine the points E, U, &c. Secondly, the *direction* of shadows is found by the intersection of the plane receiving the shadow with the plane of rays that contains the line casting the shadow. Thus A T (fig. 4) is the intersection of the ground plane with the plane of rays A L T. In like manner A E, (fig. 1,) A U, A C, and A I, are similar intersections on the ground plane made by their respective planes of rays.

Obs. 7. That the several planes containing the sun's rays may be classed according to the three cases mentioned in Art. 34. Either these planes of rays will be *parallel*, or *perpendicular*, or *inclined* to the perspective plane. Let the student, placing himself in the sunshine, remark in what direction his own shadow falls. Suppose him standing with the point S (fig. 2) between his feet and the vertical line S V passing through his eye at *e*. Either this plane of altitude containing the vertical line S V may be parallel to the picture, or it may be perpendicular, as V D P *o* S; or it may be inclined, as are V R Q C, and V M N E.

Obs. 8. That if the luminary be in the zenith, emitting vertical rays parallel to V S, it is evident that all the planes of rays will be parallel to the plane of the picture. The man's shadow on a horizontal plane beneath will be no other than a horizontal section (see Obs. 4) of the thickest part of his person. All lines of rays on the picture must here be parallel to P *o*. But imagine the sun (still in this parallel plane) to be in the horizon as at sunrise or sunset. The lines of rays now will be parallel to H L in a direction towards the spectator's right or left hand. Shadows cast on planes parallel to the station plane will now be sections of the shadowing object, (Obs. 4,) while shadows cast on the ground plane or its parallels will be interminable. (Obs. 5.)

Obs. 9. That when the sun's rays are parallel to the perspective plane, in other words, when the sun is in the plane of the picture, (fig. 4,) the shadows of all lines parallel to the picture will be parallel to the vanishing line or base of whatever plane they are cast upon. Thus T *s*, the shadow of a portion of T P, is parallel to H D; *s p*, the shadow of the remainder of T P, is parallel to S D. So also R *h*, and *h k*, shadows of K R, are parallel to the vanishing lines of their respective planes. And on the roof vanishing in W D, the shadows *e n*, *o u*, and *i j*, of lines parallel to the picture, are represented parallel to W D.

Sun's rays parallel to the picture.

It will be now proper to apply Problem III. to the representation of shadows when the sun's rays are *parallel* to the plane of the picture.

Given then the angle A T L (fig. 4) of the sun's altitude and a point L, to find the shadow of the point L. Find its seat (Def. 8, and Prob. I.) at A. Draw through the seat A the intersection A T of the plane of the rays with the ground plane, the latter being the plane which here receives the shadow. (Art. 141, No. 1.) This gives the *direction* (Obs. 6) of the shadow. Lastly, through the given point L draw a line parallel to the given rays. Produce this line (L T) till it cuts at T the line of direction. T is the shadow of A. Thus may be found the shadow of any other point having A for its seat. In like manner *z* the seat of Y being found on the plane H *d c s*, to find the shadow of Y draw the vanishing line S D of the plane receiving the shadow. (Obs. 6.) Through H, the vanishing point of the perpendicular Y *z*, draw a ray H S parallel to L T, *i. e.* making at H the angle D H S of altitude. H S will be the vanishing line of the plane of rays containing Y *z*, (Art. 31,) and of all other parallel planes of rays. (Art. 65.) Next, from the vanishing point S of the intersection of this plane with the plane H *d c s* draw S *y* through *z*. A ray parallel to L T through Y will now give *y* for the shadow of Y at the point where Y *y* meets S *y*.

Cor. 1. Thus may be shown that the shadows of the parallels vanishing in H will be lines vanishing in S.

Or the point of shadow *y* may be found by finding the shadow R *w* on the ground plane of a line K R containing Y. Where that shadow is cut at *h* by the plane H *d c s*, change its direction to *h k*. (Obs. 2.) The ray Y *y* from Y will cut *h k* in the point *y* required. This latter method is sometimes the more convenient of the two.

When, for instance, the shadow changes to a new plane $dabc$, where ij, ou, and en, to show the direction of the shadow, are drawn through the points j, u, and n, parallel to W D; (Obs. 9;) instead of drawing ix, or ex from x the intersecting point of H S with W D, (Art. 145,) let rays O o, I i, E e, parallel to S H or L T, be drawn through I, O, and E. These will give i for the shadow of I; o for that of O, &c.

Obs. 10. We have now seen that the representations of the shadows of lines parallel to V S, (fig. 2,) or parallel to the picture, will be parallel to the bases of whatever plane receives them. (Obs. 9.) Thus represented on a horizontal plane, they would be parallel to H L; on a plane vanishing in P o, they would be parallel to P o; on a plane vanishing in R Q they would be parallel to R Q, &c.

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Let us next observe that if the rays be *perpendicular* to the picture, the line V S will be in the station plane. (Art. 17.) The spectator, for example, with the sun just above the horizon, shining directly at his back, (and in the station plane,) and giving rays parallel to A a, will see his shadow along the line S o, in a direction parallel as before (Obs. 8) to the solar beams. The lines, therefore, both of the spectator's shadow, and of all other horizontal shadows, will vanish, together with the lines of the rays, at a, the centre of the vanishing line of the plane to the base of which they are perpendicular, (Art. 72,) namely, in the centre of the picture. (Art. 73.) The lines of shadow, however, will in this case be interminable, (Obs. 5,) since the sun has no altitude. But suppose the sun to continue behind the spectator and in the station plane, and to be raised above the horizon so as to make the angle of altitude A ef; the plane of altitude (or in this case station plane) will still vanish in the line P a o, (Art. 70,) but the vanishing point of the lines of rays will no longer be the same with that of the horizontal lines of shadow at a. The altitudinal intersection (Def. 11) will now vanish at d; while the horizontal (Def. 10) continues to vanish at a as before. Horizontal lines of shadows (as well as all others not parallel to fd, Obs. 5) will no longer be interminable. They will be defined and determined by the lines of rays vanishing in d.

Suppose now the sun directly in front of the spectator with rays again parallel to A a, and vanishing in a. The line of horizontal shadow S p will again be interminable in an opposite direction. But if the luminary rise to D (still in the station plane) the ray D p, vanishing at P, will cut and define the spectator's horizontal shadow at the point p; and D p o, or P e a will be the angle of altitude.

Obs. 11. The phenomena caused by planes of rays *inclined* to the picture come lastly to be considered. When the sun is in the horizon, similar appearances to those we have noticed (Obs. 9 and 10) will take place. The lines of shadows, and the lines of rays will vanish together at the same point, suppose b or c. If the luminary, with rays vanishing in b, for example, be *behind* the spectator, his shadow will take the direction S t. If the rays come *towards* him, his shadow will take the direction S F; and will in either of these two cases be interminable. (Obs. 5.) But suppose the sun's altitude over the spectator's left shoulder to be C y F = b e Q, and graduated on b Q at Q; and let C R Q be the plane of altitude vanishing in R Q. The interminable shadow in the direction S t will now be cut short at y by the ray C y vanishing at Q. Change the sun's place again, and suppose the altitude to be R e b in front of the spectator, and a little to his right; the ray R F vanishing at R will determine S F for the horizontal shadow of S e. The plane of altitude (Def. 9) will be R e Q vanishing in R Q, but having the vanishing point of altitudinal intersection (Def. 11) above the horizontal line at R instead of below it, as before, at Q.

The student may apply this observation to similar phenomena when the sun is in any other plane of altitude, as for example, the plane E M N vanishing in the line M N. In this example the rays either proceed from behind the spectator, and pass over his right shoulder to vanish in N, or they vanish at M not quite in front of him, and towards his left hand.

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We are now prepared for the application of Problem III. to the representation of shadows caused by planes of rays *inclined* to the picture.

Draw the horizontal line H L, (fig. 1, or 2,) and at C, the centre of the picture, raise either above or below H L a perpendicular equal to the principal distance. (Art. 22, 28.) At X, (fig. 1,) its further extremity, let an angle be made with C X equal to the complement of the given angle made by the plane of altitude.

Obs. 12. The question now is, on which side of C X to make the angle; towards C L, or towards C H. The place of the sun decides the question. If the sun be behind the spectator, and if the plane of altitude (suppose C R t F, fig. 2) take the direction F t or C Q over his *left* shoulder, then the angle (which must equal o S t) will be made to the right of a, (fig. 2,) or of C. (Fig. 1.) If from behind, over his *right* shoulder, in the direction S i, (fig. 1,) the angle i S o must be made to the left of a, or C, the centre of the figure. But when the sun shines towards the spectator's face as from B or D, (fig. 1,) or from M, (fig. 2,) or R the angle at X (fig. 1) must be made on the same side of C X with the sun.

Prolong now the line making at X the complement of the given angle. The point where that line meets H L will be the centre, as R of the vanishing line B R of the plane, making the given angle, *viz.* the plane of altitude. On either side of that centre, as R, raise a perpendicular, as R x, to its vanishing line B R, equal to the direct distance as R X, (Art. 131,) and at the further extremity x of this perpendicular, construct the given angle B x R of the sun's altitude. Construct it above H L, if the sun shines towards the eye or face of the spectator; below, if shining at his back. (Obs. 11.) In this manner are found the vanishing points H, R, O, L, (fig. 1,) c and b, (fig. 2,) and L, (fig. 5,) vanishing points of horizontal intersection. (Def. 10.) Thus also the points M, B, D, V, (fig. 1,) N, M, R, Q, (fig. 2,) and V, (fig. 5,) vanishing points of altitudinal intersection. (Def. 11.)

Obs. 13. When, however, the plane receiving the shadow is not a horizontal plane, its vanishing line must be found, and the point where that vanishing line cuts B R, (fig. 1,) or the vanishing line of the plane of altitude, is to be the point for showing the *direction* of the shadow, and to be used as the points H, R, O, L, &c. of horizontal intersection would be, if the receiving plane were horizontal.

Thus, in the vanishing line of the plane of altitude the two points, as B and R, (fig. 1,) being found, let now T be the given point in Prob. III. of which the shadow is to be represented: say, on the ground plane. Find A its seat. (Prob. I.) Through A its seat, and from the vanishing point R of horizontal intersection (that is from the point where the two vanishing lines, (Obs. 13, and Art. 145,) that of the plane of altitude, and that of the plane receiving the shadow, cross each other) draw the line of direction, say R I. I is the required representation of the shadow of the given point T.

By the same method are found, under any other aspect of the sun, other shadows of T, as E, U, &c. In this manner also, the four shadows of the house (fig. 1) are constructed, by ascertaining first the shadows of the points d, k, g, f, h, j; and then drawing lines lm, mr, &c. for the limits of a column of shadow intercepted by the ground plane.

Cor. 2. Any horizontal plane is a plane of measure for the angle made by the plane of altitude with the plane of the picture. (Compare Art. 142, 151, 152, 187.)

To find, lastly, the shadow of any line of which the vanishing point is known.

Let the given line be kd. (Fig. 1.) Find the shadow l of some point, as d, in the given line. Prolong kd to its given vanishing point at y. Join y with the vanishing point, say D of the sun's rays, (*viz.* of altitudinal intersection,) y D will be the vanishing line of a plane of rays containing the given line K d. Remark where y D crosses the vanishing line of the *plane which receives the shadow; viz.* in this example, at P. Draw from P the intersection lm of the plane of rays $mldk$. A ray from D through k will determine ml for the shadow of kd required. (Def. 11.)

Obs. 14. We have yet to remark upon the method of constructing shadows for Prob. III. when either the line casting the shadow is parallel to the picture, or the plane receiving it is parallel to the picture.

In the former case when the given line and the given plane are parallel to each other, the direction of the shadow has been noticed. (See Obs. 2.) Where, however, the given line and the given plane are not parallel to each other, and the given line is parallel to the picture, prolong the vanishing line of the given plane till it meets that of the plane of altitude. The point of their contact is the vanishing point of the line of direction (Obs. 6) for the shadow. Thus, L (fig. 5) is the vanishing point of the shadow P r of part of the line P N, the latter line being parallel to the picture. When the direction changes to another plane, (a given plane vanishing in A B,) prolong A B till it meets L V, and again from the point where these two vanishing lines meet, draw tm, for the new direction of the shadow. Suppose, further, another plane vanishing in H O, to receive the remainder of the shadow of P N. Prolong H O to meet V L, and draw from m to their common point of contact the line mn, of which the length is determined by (Obs. 6) the ray V N.

Obs. 15. When the given plane receiving the shadow is parallel to the picture, and the given line which casts the shadow is not parallel to the picture, prolong the given line to its vanishing point; and join that point to the vanishing point of the sun's rays. Thus will be found the vanishing line (Art. 31) of a plane of rays containing the given line; and the direction of the required shadow will be parallel to the line so found. For example, prolong N z (of which the shadow is required on a plane parallel to the picture) to its vanishing point C. Find z, its point of contact with the given plane. (Art. 43, *et seq.*) Join V C. (Art. 31.) A parallel *z y*, to V C, or V W, (*viz.* to the vanishing line of a plane of rays containing N *z*,) will be the direction (Obs. 6) of the shadow of N *z*. Another example is the line *w v*, vanishing on the line A B, somewhere between H and B. Join its vanishing point to V, (Art. 31,) and draw *v u*, parallel to the vanishing line so found, of a plane of rays containing the given line *v w*. Lastly, *v u*, determined by the ray V *w*, (Obs. 6,) will be the shadow of *v w*.

Fig. 5 further exemplifies Prob. III. by the representation of the shadows thrown upon three successive planes from the divisions of a window frame. First, upon the ground plane; the shadows of *i l*, *g h*, &c. perpendicular to the picture vanish with the lines themselves in the centre C of the picture, (Obs. 2,) and have their lengths (Obs. 6) determined by rays V *i*, V *l*, V *g*, V *h*; while the parallels to the picture in the direction *i g*, *l h*, &c. have their shadows vanishing in L. (Obs. 14.) Secondly, on the plane that vanishes in A B the shadows of parallels to *i l*, and *g h*, vanish at the point where V W, the vanishing line of their plane of rays, (Def. 1,) cuts A B, the vanishing line of the plane receiving their shadow. (Obs. 14.) Thirdly, on the plane in the distance, parallel to the picture, the shadow of the line *l h* at *o*, will be parallel to the line itself. (Obs. 2 and 14.)

Other examples are given in the foreground of fig. 5 which seem to require no further observation here, and which the student, after the rules above given, may work out for himself, with the exception, perhaps, of the following. The shadow of a plumb line is cast upon a cylinder. Find *p*, the seat of any point in the plumb line on the ground plane. (Prob. 1.) Draw *p* L and *x j* for the shadows of the plumb line on the ground plane and on a plane vanishing in A B. (Obs. 14.) Construct a circular section of the cylinder perpendicular to the ground plane. Divide the section by a diameter representing a parallel to the ground plane, and also by perpendiculars crossing it between *q* and *s*. Draw *q* H, *s* H, and between them draw the representations of any number of parallels crossing *p x*. At the points where they cross *p x* raise perpendiculars; as also between *q* and *s* on *q s*. Let these perpendiculars meet a like number of parallels to *s* H on the upper surface of the cylinder. The points thus found above *p x* will show the curve formed by the shadow of the plumb line.

Note (B.)

The science of reflections has reference to three particulars. 1. the reflecting surface. 2. The object to be reflected. 3. The reflected image of the object. Respecting the first of these particulars, we have only space for some observations concerning polished *plane* surfaces. Respecting the other two particulars we shall treat of them as likewise forming portions of planes.

Obs. 16. The three planes thus distinguished will have a common line of intersection, *e a* (plate x. fig. 5) or *b a*. (Plate xii. fig. 3.)

1. The reflecting plane, as *c d e*. (Fig. 2.)

2. The plane that contains the object to be reflected, as *a* I O *b*, (fig. 3,) or *a b d e*. (Plate x. fig. 5.)

3. The plane that contains the reflected image of the object, as *a g h e*, (fig. 5,) or *a i o b*. (Plate xii. fig. 3.)

Obs. 17. Their common line of intersection, when parallel to the picture, as *c o*, *p q*, or *r s*, (plate x. fig. 5,) will be parallel to W X, the vanishing line of their reflecting plane. (Art. 143.) But when not parallel to the picture, their intersection will vanish where the three vanishing lines, or any two of them, cross each other. (Art. 145.) Thus the common intersection *e a*, (fig. 5,) vanishes at C where the vanishing lines W C X, (of the reflecting plane,) V C T, (of the plane that contains the object to be reflected,) and H C R (of the plane for constructing the reflection) cross each other.

Obs. 18. Upon the position of this line of intersection with respect to the spectator, and also upon the position of the reflecting plane depends chiefly the correct delineation of reflections. For

This line of *intersection*, as also the reflecting plane may be either
parallel, (Obs. 20.) or
perpendicular, (Obs. 24,) or
inclined, (Obs. 28,)
to the picture.

Obs. 19. If the reflecting plane be parallel to the picture, the images reflected will be merely a perspective representation of that side of the objects to be reflected which is unseen by or behind the spectator. We shall therefore in the two following problems confine our attention to the other two positions of the reflecting plane; as perpendicular to, and as inclined to the picture.

Prob. IV.

Obs. 20. PROBLEM IV. *Given a reflecting plane perpendicular to the picture*, (as, for example, the surface of smooth water.) *to find the reflection of any given line.*

Intersection parallel.

1. Let the *intersection* of the reflecting plane and of the plane containing the object to be reflected *be parallel*, (Obs. 18,) as *c o*, (plate x. fig. 5,) *to the picture*, and let the reflection be required of a line *c y*, which is also parallel to the picture. Prolong *c y* at its extremity *c*, (*c* being the seat of *y*,) till *c f* equals *c y*. *c f* will be the reflection of *c y*. In the same manner is to be found *o k*, the reflection of *o z*.

Or, let it be required to find the reflection of *y z*, also a parallel to the picture, but having another direction. Find *c*, the seat (Def. 8, Prob. 1.) of *y*, and *o*, the seat of *z*. Find also the reflection *c f* and *o k* of *c y* and *o z*. Then join *f k*. The reflection of *y z* will be *f k*.

Obs. 21. Let it next be required to find the reflection of the line *i u*, (fig. 5,) perpendicular to the picture. Find the points *j* and *t*, by the method above stated, (Obs. 20,) and join *j t*, which will be the reflection sought.

Or, let the reflection be required of *x c*, inclined to the picture. Draw C *m*, which obtains *m* for the seat of *x*. (Prob. I. No. 2.) Make *m n* equal to *m x*. Then join *n c*. The reflection of *c x* will be *c n*. In like manner, *o j* reflects *o i*, *o t* reflects *o u*, &c.

Obs. 22. The angle of inclination here made by a plane with the reflecting surface may be made either *from* or *towards* the spectator. It is *from* the spectator when it lies beyond a plane passing through the line of intersection, and perpendicular to the reflecting surface. Thus the angle *u o* C (fig. 5) made by the plane *c u* with the surface of the water, is an angle *from* the spectator; because the plane *c u* is beyond the plane *c y z o*, perpendicular to the water.

On the other hand, the angle of inclination made with the reflecting surface is *towards* the spectator when made on this side of the perpendicular plane. Thus the angle *x c m*, made by the plane *x o* with the reflecting plane, is *towards* the spectator; *x c* being on this side of *c y z o*.

Observe a separate example (on the intersection *p q*) of a reflection with the angle *towards* the spectator; and another (on the intersection *r s*) with the angle *from* the spectator.

Obs. 23. The vanishing line of the plane to be reflected, and that of the plane containing the reflection, will lie on different sides of W X, the vanishing line of the reflecting surface. If the vanishing line, for example, of *c o u* (the plane to be reflected) crosses B A at B; the other vanishing line of the plane *c o t* (containing the reflection) will cross B A at A. Remark also that the angle graduated at A must be of the same number of degrees as the angle graduated at B. In other words, the central distance C A must equal the central distance C B. (Art. 24, 148.) So also of the plane *x i o c*, reflected in the plane *n j o c*, the vanishing line of the former crossing at A must have a central distance A C equal to that of the latter crossing at B on the opposite side of W X.

Intersection perpendicular.

Obs. 24. The next division of the problem refers to *planes of which the intersection with the reflecting plane is perpendicular to the picture.*

2. Let *e a* be the common intersection, (Obs. 17,) which being given perpendicular to the picture, must vanish at C. (Art. 73.) Make at C, upon the reflecting surface, and with its vanishing line W X, any given angle of incidence V C W. Next, on the other side of W X, (beneath, as it were, or within the reflecting surface,) make the angle of reflection W C R = V C W, the angle of incidence. V C, or V T, is the vanishing line of *a b d e*, the plane to be reflected, and R H the vanishing line of *g a e h*, the plane containing the image or reflection.

Obs. 25. The reflection here of lines parallel to the picture must be drawn parallel to the vanishing line of the plane containing the image. Thus, as *e d* is parallel to V T, so *e h*, the reflection of *e d*, must be parallel also to the vanishing line of its plane, namely, parallel to R H. Likewise, *a g* must be parallel to R H, just as *a b*, its prototype, is parallel to V T. Prolong, therefore, any portion of *d e*, or of *b a*, till they touch the reflecting surface, and through the point of contact *e*, or *a*, draw *e h* parallel to R H, and equal to *e d*; and *a g*, another parallel, equal to *a b*. These will be the reflections respectively of *e d* and *a b*.

Obs. 26. For the reflection of lines perpendicular to the picture, as *d b*; find *l* the seat of *b*, (Prob. I. Def. 8,) and make *l g* (Obs. 24) equal to *l b*. *g* will reflect to the furthest extremity of *b d*. In the same manner, find *h*, the reflection of the nearest extremity. Draw *g h*, for the reflection of *b d* required.

Obs. 27. For the reflection of any other lines in the plane *b a e d*, draw an occasional base or parallel to *e d* and V T through the given lines, and let their vanishing points be noted on V T, the vanishing line of their plane. Next, find their dividing points, and bring each line to its proper full length on the base. Prolong the base to meet the line *e a* of intersection, and draw through the point of contact a corresponding base or parallel to *e h* and R H, on the plane vanishing in R H. For example, make C H 30° equal to C V 30°. (Art. 82, 88.) Thus may the reflection of the hexagon be obtained or of any other diagram.

Observe here, that the angle *b a l* made by the plane *a b d e* with the reflecting plane is made *towards* the spectator. (Obs. 22.) Another example is added of a plane inclined *from* the spectator which contains another diagram. For constructing the diagram consult Art. 98, and the 1st Book of Euclid, Prop. 47.

ersection lined.

Obs. 28. The concluding division of this problem refers to *planes of which the intersection with the reflecting plane is inclined to the picture.*

3. Let *u r* (plate ii. fig. 3) vanishing at P, and, consequently, inclined to the picture, be the common intersection, and let P C be the vanishing line of the reflecting plane. Let here a similar process be pursued as with the intersection perpendicular to the picture, (Obs. 24,) only let the given angle of incidence, and, consequently, of reflection, be made at P. It will be found that the plane *g r* contains any reflected image of the plane *b r*; *h r* of *a r*; and *f r* of *d r*. The plane *j r e u* is a portion of the reflecting surface perpendicular to the picture.

b. V.

Obs. 29. Problem V. *Given a reflecting plane inclined to the picture,* (as, for example, a plane mirror or other polished plane surface,) *to find the reflection of any given line.*

It will be necessary to consider this problem also in its reference to the different positions of the common intersection. (Obs. 18.) 1. When the latter is inclined; 2. when it is parallel to the picture. The third case of a perpendicular intersection belongs exclusively to the preceding problem, since all vanishing lines that pass through the centre of the picture must belong to planes perpendicular to the picture. (Art. 65. Also see below, Obs. 32 and 34.)

rsection lined to perspec- plane.

1. When the *common intersection,* as *a b*, (plate xii. fig 3,) is *inclined to the picture.* Let H be its vanishing point; H M the vanishing line of the reflecting plane *c d e*; and M W the vanishing line of the plane of measure. (Art. 146, 182.) It is required to find the reflections (represented on the plane *c d e*) of the line L *b*, and its plane L *a*; of O *b* and its plane O *a*; of K *b* and its plane K *a*; of N *b* and its plane N *a*; and of P *b* and its plane P *a*.

Obs. 30. To begin with the reflections of the plane L *a* perpendicular to the reflecting plane. Let L *b* be produced to its vanishing point W, the vanishing point of all perpendiculars to any plane vanishing in H M. (Art. 196.) The angle L *b* S or M *b* W represents the angle made by the plane L *a* with the reflecting plane, *viz.* an angle of 90° as measured on the vanishing line of the plane of measure, *viz.* 25° on one side of R, and 65° on the other side, 25 + 65 = 90. For determining the length of *b l* raise first the direct distance at R, (Art. 130,) then draw an occasional base E C (through *b* parallel to M W) of the plane of measure. On this base mark off by means of the dividing point (Art. 85, 98) of *l* W (to be found between W and M) a portion, as N *b*, equal to the original of L *b*, as seen at the distance of *b*. From *b* C take off a portion equal to *b* N. A line from the same dividing point will cut *b* W in *l*; and *b l* will be the reflection of *b* L.

Obs. 31. In the vanishing line of the plane L *l a*, observe that two points are found: H, the vanishing point of the common intersection with the reflecting plane; and W, the vanishing point of intersection with the plane of measure. Join H W. It will be the vanishing line of the plane L *l a*, (Art. 31,) which contains on one side of *a b* the objects to be reflected, and on the other their reflected images.

Obs 32. For the reflexes of the planes O *a* and K *a* inclined *towards the spectator,* (Obs. 22,) let the plane O *a* make an angle represented by S *b* O or M *b* D of 47° (*viz.* 25 + 22 = 47) with the reflecting plane. It is required to find the reflexion of O *b*. For this purpose count the same number, 47, of degrees along the vanishing line of measure on the side of M opposite to M D. Add 47° to 25°, the number marked at M. (Art. 111.) The result will be the vanishing point marked 72 (or 47 + 25 = 72) of the line of reflexion *b o*.

Again, let the plane K *a* make with the reflecting plane an angle, represented by K *b* S, of 69 degrees, namely 25 + 44 = 69. To 25 degrees marked at M add 44° marked at the vanishing point of K *b*. For the vanishing point of the reflection let 69 be added to 25. 69 + 25 = 94. Out of this number, ninety are disposed of in the parallel C E. The remaining four degrees must therefore be reckoned along M W on the same side of R with the vanishing point of K *b*. Subtract 4° borrowed from that side. Consequently 90 − 4, or 86°, will be the number graduated on R W produced for the vanishing point of *b k*, the reflection of *b* K.

Obs. 33. The lengths of the reflections *b o* and *b k* may be determined by drawing lines O W and K W, representing perpendiculars to the reflecting plane. (Obs. 30.) O W will cut *b o* in *o*, and K W will cut *b k* in *k*, and thus determine the lengths.

Obs. 34. Respecting the vanishing lines of the four planes O *a* and its reflection *o a*; K *a* and its reflection *k a*: observe that they pass through the two vanishing points analogous to those mentioned in Obs. 31, namely, through H, the vanishing point of common intersection, and through the other vanishing point (in M W) of intersection with the plane of measure. A straight line through H and D, for example, will be the vanishing line of the rectangle *a* I O *b*.

Obs. 35. For the reflection of the remaining planes N *a* and P *a inclined from the spectator.* (Obs. 22.) Let the plane N *a* make with the reflecting plane an angle of 65° represented by N *b* M. Here it is evident that N *b* must coincide with E C. The 25° marked at M being added to 65° will complete the right angle. (25 + 65 = 90.) To find the reflexion of N *b*; note the difference between 25 and 65, or the point marked 40° on the other side of R. This point is the vanishing point of *b n*, the reflection of *b* N.

Again, let the plane P *a* be reflected, making an angle of 21 degrees with the reflecting plane; namely, vanishing at a point graduated 46°, between which number and 25° (marked at M) there must be that difference. (Art. 111.) To find the reflection. Deduct, on the opposite side of M, 21 degrees, (25 − 21 = 4,) and *b p* vanishing at the point marked 4° will be the reflection representing, by M *b p*, an angle equal to the angle of incidence, or 21 degrees.

Obs. 36. The lengths of the reflections *b n* and *b p* are determined as in Obs. 33, by representations of perpendiculars drawn to W through N and P.

Obs. 37. Respecting the vanishing lines of the four planes N *a* and its reflection *n a*; P *a* and its reflection *p a*; they are drawn through H in the same manner as those in Obs. 33. Only observe that the vanishing line of N *a* (drawn likewise through H) must be parallel to E C, (Obs. 35,) and consequently will not cross M W, the vanishing line of measure. The plane N *a* is, in fact, perpendicular to any plane vanishing in H R. (Art. 153.)

Obs. 38. Corollary. The above construction, supposing the points O K L N P to be points in a curve, would suffice for delineating the reflection of the curve by a line through the corresponding points *o k l n p*. The reflection, for example, of any arch of a bridge, might be obtained by adapting to Prob. I. an operation similar to that just stated, and by making the reflecting plane or *o d e*, represent a smooth surface of water perpendicular to the picture, and with H R for its vanishing line.

Intersection parallel to the perspective plane.

Obs. 39. The other remaining division of this problem regards the position of the *common intersection as parallel* (Obs. 29) *to the picture.*

2. Let *c o* (plate x. fig. 5) be the common intersection; (Obs. 17;) A the centre of the picture; and W X the vanishing line of a reflecting plane which is inclined to the picture. It is required to find the reflection (as in Prob. IV. Obs. 20 and 21) of a line (as *c y*) perpendicular to the reflecting plane; or parallel, as *y z*; or inclined, as *x c*.

Obs. 40. The reflection of *c y* is obtained in the same manner as that of *b* L. (Obs. 30. plate xii. fig. 3.) Since A (plate x. fig. 5) is given as the centre of the picture, the line *c y* will vanish in the vanishing point of all perpendiculars to the plane that vanishes in W X; and its reflection *c f* (as a continuation of *c y*) will vanish in the same point with *c y*.

Obs. 41. The reflection of *y z* may also be obtained as before, (Obs. 20,) by first ascertaining the reflections of *c y* and *o z*, (Obs. 39,) and then joining by a line, as *f k*, the reflections *f* and *k*, of its extremities *y* and *z*.

Obs. 42. The reflection *x c* (Obs. 39) inclined to the picture and to the reflecting plane may also be obtained as before, (Obs. 21,) by prolonging it to its vanishing point A; and ascertaining its angle as graduated on B A, the vanishing line of the plane of measure. (Art. 82, 148.) Then on the other side of W X reckon from C, the centre of that vanishing line, towards B an equal number of degrees to those marked between A and C. If B be the point so found, join B *c*, which produced to *n* will give *c n* for the reflection of *c x*.

Obs. 43. From want of space we here use a diagram from plate x. fig. 5, in illustration of these remarks, (Obs. 39,) instead of one more geometrically correct. It must be plain to the geometrical reader that *y f*, vanishing at some point in B A produced, cannot be parallel to B. A. Our student, however, will not find it difficult, nor we trust unprofitable, to reconstruct the diagram for himself.

Obs. 44. An example for Prob. V. will be found (plate x. fig. 1, No. 6) in *μ g h p*, which forms the reflection of the pyramid *μ g h e*: (Art. 213:) provided that the base *μ g h* of the pyramid coincides with the reflecting plane which vanishes in a line drawn through U parallel to *g h*.

Other examples may be drawn also from plate x. (See fig. 1, Nos. 5, 7, and 8) If *d a b c* (No. 5) be supposed the base of a four-sided pyramid placed on a polished surface that vanishes in H L, this will be an example for Prob. IV. and *a e b* will be the reflection of the pyramid. Also if a similar division be made of the dodecahedron No. 7, (Art. 213,) its upper half with the apex *a* will be reflected by its lower half with the corresponding apex *b:* supposing the base of the upper half to vanish in P D for the vanishing line of the reflecting plane. Again, let the dodecahedron (Art. 213) No. 8 be similarly bisected; and let the plane of its bisection (*viz.* the reflecting plane) vanish in P D. The representation of its lower half will, in like manner, represent the reflection of its upper half.

Note (C.)

Light and Shade.—Obs. 45. If from any point of a reflex two straight lines be drawn to the boundary of the enlightened surface causing that reflex, and if a third line be drawn as a base to complete the triangle, the degree of light at the reflex will be greater in proportion as the angles at the base approach nearer to an equality.

Let L (plate vii. fig. 7) be the sun's light passing through an opening in the dome A K R X B: let Z V be a line drawn on an enlightened surface: and suppose the light on K to be transmitted between equal angles, or angles nearly equal. In this situation it is evident (on account of the two triangles on the same base Z V) that the reflex K will have a greater inequality between its angles K Z V and K V Z at the base, than the reflex R has between its angles R Z V and R V Z. Consequently, the point R will receive more light than the point K: and the reflex at X with the angles at Z and V, equal to each other, will be most luminous. Also the point R being nearer the enlightened body than K will be brighter. (Da Vinci, cap. 80.)

Obs. 46. Reflexes when double are brighter than when single.

Let L, for example, (fig. 6,) be a luminous body, L P and L U direct reflexes; P and U parts illumined by L: D and G parts of the same bodies illumined by the reflexes; L P G a simple reflex; L P D and L U D a double reflex; the simple reflex G is formed by the enlightened body P T, and the double reflex D by the two enlightened bodies S T and T U. Hence additional brightness at D, while any shadow of that double reflex will be so thin as to be scarcely visible; being found between the incident light, and that of the reflex P D, U D. Da Vinci, cap. 83. (*The letter* G, *at the extremity of the parallel to* A U *through* P, *has been inadvertently omitted in the plate.*)

Obs. 47. Of various reflexes the most powerful comes from the least distance. (Cap. 78. 124.)

Obs. 48. The darkness of the ground receiving a reflex (whether that darkness be made by the local colour of the ground, or from its being in shade) causes a sensible difference in the brightness of the reflex. If the reflex be cast on a light or bright ground it will not appear to impart much light, but when cast on a dark and shady ground, will be more distinctly visible in proportion to the depth of shade receiving it. (Cap. 82. 86.)

Colour.—Obs. 49. When a reflex from a coloured surface falls on another surface of the same colour, the latter becomes more vivid. Thus in the folds of drapery the local colour is deeper and more vivid where light is reflected by one part of a fold upon any other part. The reflexes, in like manner, of the human skin, are of a deeper and redder carnation, when in the vicinity of other carnations. (Cap. 81. 125.) The same appearances are given by reflexes from one object upon any other separate object of the same colour. Suppose L (plate vii. fig. 7) a light, Z V a body directly illuminated by it; X another body, out of the reach of L, and only receiving light from Z V, which is supposed of a red colour. In this case the light communicated from Z V, deriving its hue from the local colour of the body, will tinge with red the opposite body X: so that if X were of a red colour before, its redness will now be heightened and rendered much brighter than the red of Z V; but supposing X to have been yellow before, then a colour will result which partakes of both. (Cap. 117. 125.)

Obs. 50. Where different coloured reflexes having the same degree of light are cast upon any colourless surface, the latter will receive its deepest tinge from the nearest reflex, and will receive likewise various additional tints from the others proportioned to their nearness. The object, therefore, reflecting its colour with the greatest vigour upon an opposite body is that which has no colour near it, but of its own kind; and on the contrary of all reflexes, that produced by the greatest number of objects of different colours will be the most dim and confused. (Cap. 86. 124.) This phenomenon may be thus illustrated. Let P (plate vii. fig. 6) be a yellow colour reflected upon the point D of the spherical interior B G D A, and let the blue colour U have its reflex upon the same point D. By the mixture of these two colours in D the reflex will be converted into a green, if the ground be white. (Cap. 85.) For a white surface is better disposed than any other for the reception of a coloured reflex. (Cap. 123.)

Obs. 51. But variations in reflexes are caused not only by the local colour of the reflecting surface, but also of the body receiving the reflex. These two local colours mingle and form a third. Thus suppose the spherical interior B X R A be of a yellow colour, and the object Z V blue, and let X be the point where a reflex sent from Z V strikes upon B X R A, the point X in this case will become green.

Obs. 52. All reflected colours, and colours of reflexes, are less vivid than coloured surfaces which receive light from self-luminous bodies; in the same degree as the force of reflected rays must be weaker than of original or primitive rays. (Cap. 87.)

Obs. 53. A reflex from a dim or obscure body upon another of a colourless obscure is scarcely perceptible; while on the contrary, a reflex from the latter upon the former communicates very sensibly both light and colour. (*Ibid.*)

Obs. 54. Shadow produces similar appearances. A coloured reflex upon a shadowed surface is brighter and more distinguishable in proportion to the depth of shadow. (*Ibid.*)

Note (D.)

"From the foundation of the Venetian school a mode of proceeding was adopted, which, though well calculated to give the Painter a greater promptness of execution, a more commanding dexterity of hand, and a more chaste and lively colouring than is to be found in the artists of the Roman or Florentine schools, was also the means of introducing a want of correctness, and a neglect of purity in their outline. Their method was to paint every thing without the preparation of a drawing; whereas the Roman and Florentine Painters never introduced a figure of which they had not studied and prepared a model or cartoon. Following the system of his countrymen, Titian painted immediately from Nature; and possessed of a correct eye, attuned to the harmony of effect, he acquired a style *of colouring* perfectly conformable to truth. Satisfied with this *identity of imitation*, he was little sensible of the select beauty of form, or the adaptation of that characteristic expression, so essential to the higher order of Historic Painting. In his works of that description, if we look for the fidelity of the Historian, he will be found, like other artists of his Country, little scrupulous in point of accuracy. He neither presents us with the precise locality of the scene, the strict propriety of the costume, nor the accessories best suited to the subject, attributes so estimable in the works of those Painters who consulted the best models of antiquity.

Raffaelle and Titian, says Sir Joshua Reynolds, (in his eleventh Discourse,) seem to have looked at Nature for different purposes; they both had the power of extending their view to the whole; but one looked only for the general effect as produced by *form*, the other as produced by *colour*. We cannot, he adds, entirely refuse to Titian the merit of attending to the general form of his object as well as colour; but his deficiency lay, a deficiency at least when he is compared with Raffaelle, in not possessing the power, like him, of correcting the form of his model by any general idea of beauty in his own mind. In his colouring, he was large and general, as in his design he was minute and partial: in the one he was a genius, in the other not much above a copier.

"As Titian," continues Mr. Northcote, "contented himself with a faithful representation of Nature, his forms were fine when he found them in his model. If, like Raffaelle, he had been inspired by a genuine love of the beautiful, it might have led him to have courted it in selected Nature, or in her more attractive charms as found in the polished graces of the antique. The purity of his design thus united to the enchanting magic of his colouring, would have stamped him the most accomplished master the Art has produced." Northcote, *Life of Titian*, vol. ii. p. 60.

Note (E.)

"In Titian's pictures the tones are so subtly melted, as to leave no intimation of the colours which were on his palette, and it is perhaps in that respect that his system of colouring differs so essentially from that of Rubens, who was accustomed to place his colours one near the other with a slight blending of the tints. He observed that in Nature every object offered a particular surface or character, transparent, opaque, rude, or polished; and that these objects differed in the strength of their tints and in the depth of their shadows. In this diversity he discovered the generality and perfection of his Art. In imitating Nature, he took, as Mengs observes, the principle for the whole. His fleshy tones, composed in Nature chiefly of demitints, he represented totally by demitints, while he divested altogether of demitints those parts in which few were discernible in Nature. By these means he arrived at an indescribable perfection of colouring." *Ibid.* p. 65.

HERALDRY.

HERALDRY.

eraldry.

finition.

HERALDRY, which, from its connection with PAINTING, may be introduced in this portion of our Work, may be defined "The Art of blazoning and assigning Coat Armour;" or, more diffusely, "The theory of classifying, adapting, and explaining certain conventional distinctions impressed on shields and military accoutrements." The definition of this artificial Science is not a little important in the investigation of its History. Inaccuracy in this respect has led to the most discordant opinions regarding its origin. Not to mention the famous *Book of St. Albans*, which gravely informs us that the Angels are "in cote armoris of knowledge," and the Pedigree of the Saxon Kings in the College of Arms, London, which exemplifies the bearings of Noah and Japhet,* the enthusiastic but authoritative Gwillim removes the origin of his favourite Art only one generation lower, making it proceed from "Osyris, surnamed Jupiter the Just, son to Cham, the cursed son of Noah, called of the Gentiles Janus;"† whilst Mr. Hallam, following many respectable authorities, places the invention of armorial blazonry in the XIIth century.‡ Scarcely any two professed writers on the subject are agreed on the precise point whence to date their Histories. But this variation is not in reality any argument of obscurity in the matter. Each author has assumed an epoch in the History of Heraldry as its original; but, with the exception of those epochs, the progress of the Art has been an imperceptible transition from the simplest principles to its present intricate and scientific construction. We shall not, therefore, attempt to assign any exact period to its invention, but prefer tracing the Science of Arms from the first rude emblems of warlike adventurers and independent settlements to the knightly cognizances of the Court and the Tourney.

HISTORY OF THE SYSTEM.

I. *Personal Heraldry.*

tian ldry.

We cannot with Gwillim extract from Diodorus Siculus the arms of Osiris, Hercules, Macedo, and Anubis; nevertheless, we think it highly probable that significant devices on shields and military implements were in early use among the Egyptians. The practice of adorning the shield with some expressive device must be almost as ancient as the weapon itself; this, the nature of Man warrants us to conclude; but there are some circumstances which might give the Egyptians an inclination to extend and improve a practice founded in human propensity. The recent discoveries in Hieroglyphics, while they have proved the existence of a Hieroglyphical alphabet, have also, in part, confirmed the popular opinion, and shown that many of the Egyptian characters were truly symbolical. The high antiquity of those symbols is admitted; and it is quite incredible that, employed as they were in every variety of appropriation, they should have been absent from the decorations of the Egyptian hero; while the early civilization of Egypt will lead us to expect a proportional superiority in the ornamental Arts.

History.

Jewish Heraldry.

Among the earliest opinions respecting Heraldry, we may here notice the celebrated tradition of the Rabbins, respecting the Standards of the Hebrew Tribes. That the Tribes of Judah, Ephraim, Dan, and Reuben, were distinguished by peculiar ensigns is positively asserted in the Pentateuch.* The Rabbinical writers inform us that these were banners respectively charged with the figures of a lion, an ox, an eagle grasping a serpent, and a man. But this opinion has been rejected for the soundest reasons. There are no traces of any such distinctions either in the Bible or in any authoritative History. The tendency of the Jews to idolatry, and their late converse with animal objects of adoration in Egypt, render it extremely improbable that any thing of the kind should have been permitted. The whole policy of the Jewish Law is so strongly opposed to the very principles of Heraldic decoration, that the History of that People is certainly the very last wherein we might hope to collect materials for the illustration of the present subject. We think that there is much probability in the conjecture of many commentators, that the Standards of those Tribes bore simply their several names; especially as the Maccabees are supposed to have borne in their banner the letters from which they derived their name, מ כ ב י, the initials of מי כמך באלהים יהוה, "Who among the gods is like unto thee, O Lord?"

Greek Heraldry.

Among the Greeks, however, with whom no similar obstacles subsisted, Heraldry had early attained a considerable perfection; to them, according to Herodotus, the Art was derived from the Carians.† We use the term *Heraldry* advisedly. The Art, it is true, had no connection with those public functionaries from whom it afterwards received its name, and who were as well known and as distinctly recognised in the Heroic times as in the days of Chivalry. It was not till the establishment of Colleges of Arms (institutions subsequent to the latest periods assigned for the origin of Heraldry) that such a connection entirely subsisted. But the Art of adorning military habiliments with expressive devices was in high advancement among the Greeks. If the bearings of the Seven Chiefs who besieged Thebes, so gorgeously blazoned by Æschylus and Euripides, be traditional, the enthusiastic Heralds of the XVIIth and earlier centuries would scarcely exaggerate the antiquity of their Art. But, without settling the question of the existence of a Trojan war, which our sceptical Age has mooted, we can scarcely deny to the Poems of Homer and Hesiod a very considerable antiquity; and the shields of Achilles and Hercules, so elaborately described by those Poets, prove that, in their time at least, the Art had made important progress.‡ The principles of ornament, however, adopted in these

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* That of Noah is *azure*, a rainbow proper; of Japhet, *azure*, an ark proper. But there seems to have been some disagreement among these primitive Heralds, for the *Book of St. Albans* gravely informs us, that "Jafet made first target, and therein he made a *ball*, in token of all the worlde."

† *Display of Heraldry*, ch. i.

‡ *History of Middle Ages*, vol. i. p. 146.

* *Numb.* ch. ii. *pass.* † *Clio*, clxxi.

‡ *Scutis, quibus ad Trojam pugnatum est, continebantur imagines.* Plin. lib. xxxv. c. 3.

shields, are much less methodical and appropriate than those which apply to the shields of the Antithebans; a circumstance which may lead us to conjecture that the latter are the invention of the later Poets, who lived in an improved condition of the Art. The transition from these to the present refined theory of Heraldry is so easy, that it will not be impertinent to state them. According to Æschylus, Tydeus bore in his shield a full moon, surrounded with stars; Capaneus, a naked man holding a lighted torch, *with the motto* ΠΡΗΣΩ ΠΟΛΙΝ; Eteocles, an armed man ascending a ladder placed against a tower, *with the motto* ΟΥΔ' ΑΝ ΑΡΗΣ Μ' ΕΚΒΑΛΟΙ ΠΥΡΓΩΜΑΤΩΝ; Hippomedon, Typhon, vomiting smoke and fire, surrounded by serpents; Parthenopæus, a sphinx, holding a man; and Polynices, Justice leading an armed man, with this motto:

ΚΑΤΑΞΩ Τ'ΑΝΔΡΑ ΤΟΝΔΕ ΚΑΙ ΠΟΛΙΝ
ΕΞΕΙ ΠΑΤΡΩΙΑΝ ΔΩΜΑΤΩΝ Τ' ΕΠΙΣΤΡΟΦΑΣ.

Euripides assigns somewhat different appointments to his heroes. According to his enumeration, Parthenopæus exhibited his mother Atalanta chasing the Ætolian boar; Hippomedon, the figure of Argus; Tydeus, the figure of Prometheus, holding in his right hand a torch; Polyneices, the horses of Glaucus; Capaneus, a giant bearing a city on his shoulders; and Adrastus, a hydra of 100 heads, carrying the Thebans off their walls. The shield of Amphiaraus, according to both authors, had no device.* Without urging the argument from tradition, and supposing the Poets had no authority for their devices, beyond what fancy, aided by the customs of their own time, suggested, (a supposition certainly somewhat exceeding what might be fairly allowed) we have here a proof of a very considerable advance in Heraldry so early as 450 years before the Christian Æra. A principal difference between this and the more modern system appears to be, that, in the former, *colour* is an unimportant circumstance, in the latter, essential. The devices on ancient shields were, indeed, most commonly expressed in relief on the metal; although Virgil† mentions the *picti scuta Labici*, concerning whom our want of information is to be much regretted, as the learned Poet most probably wrote from authentic tradition. Another material distinction is the absence in ancient Heraldry of every thing like *ordinaries*, which form so extensive a department of the new. But with respect to the hereditary property of Arms, this has not always been observed even since the acknowledged existence of Heraldry, as may be seen in the case of the last two Earls of Chester, the two Quincies, Earls of Winchester, and the two Lacies, Earls of Lincoln; no *positively hereditary* bearings have been found in England before Henry III.'s time; while in some instances, something like hereditary devices may be found among the Ancients, as we shall presently observe. And the assumption of Arms for a peculiar object is not confined to ancient Heraldry, since Stephen, King of England, changed the leopards into Sagittaries, on account of his landing when the Sun was in that Sign.

We have remarked here that the shield of Amphiaraus was blank. Æschylus and Euripides concur in representing this as the effect of his modesty, which would not anticipate a precarious victory. Indeed the emblems of all his companions in arms had reference to future glories. But, in some instances, heroes more prudently appealed to Memory rather than Hope, and where this was the practice, a maiden shield betokened an undistinguished warrior. Thus the youthful Helenor is designated by Virgil *parmâ* inglorius *albâ*;* and this sentiment is in strict accordance with the usages and opinions of Chivalry.† The plain shield of Camilla‡ was an emblem of purity; nor was this at all at variance with the ideas received at a more advanced period of the Art. But the instance which, above all others, seems to approximate the characters of ancient and modern Heraldry is to be found in the devices granted by Alexander to his followers, with an especial provision that the same should not be borne by any other person throughout his Empire.

Ancient crests.

Hereditary bearings.

Nor was the *Crest* unknown to antiquity, and it arose as naturally as the impress of the shield. A plain ridge of rough horsehair, which has been proved by experience an excellent defence against sabre cuts, was the first appendage to the helmet. This was afterwards doubled, tripled, and even quadrupled;§ whence the *τρυφαλεία*, *quasi τριφαλεία*, as Grammarians say, although this etymology may be disputed. Something was necessary to unite this covering to the surface of the helmet, and fancy and art soon contrived to make this supplement ornamental and emblematical. Gems and Statues furnish us abundantly with the forms of animals, &c. used in this manner. Turnus is described by Virgil as bearing for his Crest a Chimæra;‖ and Corvinus, in the Poem of Silius,¶ exhibits on his helmet a Crow. We may here observe more fully that the armorial bearings of the Ancients were occasionally hereditary. This Crow was *ostentans alcs proavitæ insignia pugnæ*; the Story of Io appeared on the shield of her descendant Turnus;** the Swan's plume on the helmet of Cupavo indicated his descent from Cycnus:†† and the Hydra on the shield of Aventinus declared him the progeny of Hercules.‡‡ The family device was frequently impressed on the hilt of the sword.§§ There is a much litigated passage of Suetonius which seems to have been very properly adduced by those who support the antiquity of Heraldry. *Vetera familiarum insignia*, says the Historian, speaking of Caligula, *nobilissimo cuique ademit; Torquato torquem; Cincinnato crinem: Cn. Pompeio, stirpis antiquæ, Magni cognomen.*‖‖ Nisbet strangely explains away this direct and positive language. "It imports no more," he observes, "than that Caligula, being displeased with the grandeur of these families, commanded to take from *their Images* or *Statues*, as from that of Torquatus, the collar or chain that he took from one of the Gauls, and from that of Cincinnatus the tuft of hair which that brave Roman

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* "Amphiaraus, (as Pindarus the Theban Poet affirmeth,) in his expedition to Thebes, bare in his shield a painted dragon." Gwillim, sec. 1. ch. i. This author is more loquacious than correct. Perhaps he alludes to Pyth. viii. 66, where this emblem is assigned to *Alcman*.

† *Æn.* vii. 796.

* *Æn.* ix. 548.

† "A young knight would not, during his first enterprises, assume his family Arms, but he wore plain armour, and a *shield without any device*, till he had won renown."—Mills, *History of Chivalry*, ch. ix.

‡ *Purâque interrita parmâ.—Æn.* xi. 711.

§ ———— ἀμφὶ δὲ καλὴ
ΤΕΤΡΑΦΑΛΟΣ φοίνικι λόφῳ ἐπελάμπετο πήληξ.
Apoll. Rhod. xi. 321.

‖ *Æn.* vii. 785.

¶ Silius Ital. v. 78.

** *Æn.* vii. 789.

†† *Ibid.* x. 187.

‡‡ *Ibid.* vii. 657.

§§ Ov. *Met.* vii. 422. Senec. *Hippol.*

‖‖ Suet. *Cal.* xxxv.

had spoiled one of the enemies of the Romans, and likewise the epithet *Great* to be defaced in the inscription of the Statue of Pompey; the word *Great* makes it evident that the other marks, the collar and hair, were not hereditary ones as Arms, otherwise the author had expressed himself thus, that Caligula caused the chain to be taken from *the Torquati*, and the tuft of hair from *the Cincinnati*, and not simply from *Torquatus* and *Cincinnatus*."[*] To all this there is a very simple reply; the devices are expressly called *familiarum insignia*. The persons mentioned were probably the heads of the several families, who alone were accustomed to wear them, and therefore alone could lose them. And that *cognomina* were sometimes hereditary is a fact too notorious to deserve insisting on. Not a syllable occurs respecting Statues, which do not seem even alluded to.[†]

Imagi-

As an instance of the existence of hereditary honours among the ancient Romans, some authors adduce the *Jus Imaginum*; but this was in reality widely distinct from hereditary armorial bearings, being only a permission to possess Statues of noble ancestors, and to parade them on the occasion of a funeral. It answered the modern purposes of Heraldry as an institution, but it had nothing in common with the theory of family devices.

We have seen then that there subsisted among the Ancients the practice of adorning the shield with appropriate figures; that they were acquainted with mottoes and crests; that, as all the inventions of modern Heraldry were not hereditary, so neither were all those of ancient ingenuity merely personal; but that colour was an indifferent circumstance, ordinaries unknown, and no peculiar phraseology in use for designating military decorations.

rowns.

But among the Ancients a species of Heraldic distinction existed which has been adopted by modern Heralds without any variation except the addition of a number of others, which are called *Coronets*. This was the *Crown*. It was either a token of office or of merit. Its various species we shall proceed to enumerate.

I. *The Eastern Crown.* A gold rim, surmounted with eight rays, five of which are visible in Heraldic representations. This Crown is found, with trifling variation, on the coins of ancient Eastern Princes, especially those of Greek extraction. It also appears on some of the coins of the Lower Empire. Although a Crown of *office* with the Ancients, it has become in modern Heraldry a Crown of *honour*, and is given to those who have distinguished themselves in the East. The Lions which support the Arms of the East India Company wear this Crown.

II. *The Triumphal Crown.* This Crown was originally a distinction of honour, being granted to Roman citizens who had achieved any great exploit in the service of the Commonwealth. It is composed of bay, bearing berries, and tied behind with a *fascia*. But being allowed to Julius Cæsar for the purpose of concealing his baldness, it was afterwards assumed by the Roman Emperors, and became the *Crown Imperial*.

III. The *Circlet*, the στέφανος of the Greeks, and *corona* of the Latins. A plain rim of gold, given to merit of various kinds. This is also sometimes found as an *insigne* of Royalty.

IV. The *Obsidional Crown*. This was granted to the successful defenders of besieged towns, or to those who had performed any eminent exploit in defence of a fortified place. It is composed of grass taken from the scene of the hero's valour. It is rarely met with, and has never, so far as we know, been adopted into modern Heraldry.

V. The *Civic Crown*. A tribute from the State to one who had saved the life of a citizen. It is of oak leaves, acorned, and is justly considered an honour of the very highest character.

VI. The *Crown Vallary*, (*corona vallaris.*) This was given to the soldier who first entered the enemy's trench. It is a plain rim surrounded by palisades in imitation of those which guarded the entrenchments of the Ancients.

VII. The *Mural Crown*, made in imitation of the battlements of a wall, to commemorate the valour of such as distinguished themselves in the attack of a city.

VIII. The *Naval Crown* was granted to those who distinguished themselves by exploits at sea. It is a rim adorned with alternate sterns and masts of ships. It is (as might be expected) often found on the Arms of Englishmen.

IX. The *Celestial Crown*, resembling the Eastern, except that each ray terminates in a star. This Crown was placed on the Statues of deified Emperors, &c. It is preserved on hatchments and funeral escutcheons.

As this species of Heraldry, which consists of emblematical distinctions granted by Princes and Governments, appears never to have fallen into disuse, so it is likely that the decorations of shields, and the fanciful variations of crests, were preserved through the darkest Ages, although with much less elegance of invention and application, and great inferiority of execution. This is, however, only a probability, as the subject of Heraldry is enveloped in the darkness with which the Gothic conquests invested every province of History. Beckman[*] affirms that regular Arms may be found on the shields of Clothair, Dagobert, Pepin, &c. and Selden[†] mentions golden seals of the French Kings, and waxen ones of their subjects, between A. D. 600 and 700; but these authors give no authority. Edmondson, however, thinks these assertions quite sufficient, considering the dignity of the persons who make them. This is a very unsafe confidence, especially in the History of Heraldry. Never, perhaps, did an Art or practice exist which has excited so much enthusiasm in proving its antiquity, or so great a disregard of facts which invalidate that opinion. Much stress has been laid on a passage common to Æginhardus and Aimonius, Biographers of Charlemagne, who say that Count Guy, to whom that Prince had intrusted the conquest of Brittany, delivered up the *arms* of the several Chiefs who submitted, with their names inscribed thereon: *arma ducum qui se dediderant inscriptis singulorum nominibus, detulit.* But the word *arma* seems capable of a much simpler interpretation than that which the Heralds advance, and which would scarcely present itself to any but a Heraldic mind. The passage in Joinville which derives the Arms of Arnold de Commenges, Viscount of Couzerans, from an ancestor who received them from

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[*] *Ancient and Modern Use of Arms.*

[†] See also Edmondson, a Herald of uncommonly phlegmatic constitution, who, instead of carrying the origin of his profession to the antediluvian times, disputes and qualifies *all* these express testimonies.

[*] *Notitia dignitatum*, diss. vi. ch. iii.

[†] *Tit. of Hon.* xi. 2.

Charlemagne, has been proved an interpolation. Edmondson busies himself about the shield delineated by Uredius in his copy of the seal of Arnulf, Earl of Flanders, (A. D. 941;) but the words of Uredius, who spoke from actual inspection of the impression, are, *quonam id symbolo insignitum fuerit, præ vetustate non apparet;* words which make it exceedingly doubtful whether it bore a charge at all. All this, however, is merely negative evidence; and when the causes and objects of Heraldry are considered, it will be difficult to suppose that it was ever entirely neglected; and it is certain (as we shall presently show) that the Knights who contended in the Martial Games established by Henry the Fowler, actually employed emblematical and hereditary distinctions. But the prevalence of devices on the shields of sovereign Princes, will at best only prove the existence of a *national* Heraldry, which is undoubtedly ancient.

Bayeux Tapestry.

In that very curious monument of antiquity the Bayeux Tapestry, said to have been executed by the Queen of William the Conqueror, assisted by the ladies of her Court, the shields of the characters are chiefly adorned with patterns of mosaic and diaper. The four guards of Guy, Count of Ponthieu, are represented, two bearing strange monsters, and the other two, figures not very explicable, but which we have delineated in fig. xi. xii. The emissaries of King William bear a kind of wyvern. Montfaucon says, " these are no armorial decorations." This is a matter of opinion which we leave to the judgment of our Heraldic readers.

Occasional glimmerings are, however, afforded, which prove the Art to have been in existence before the Ist Crusade. The seal of Robert of Friesland, Earl of Flanders, of which Uredius gives a copy, appended to an Instrument dated A. D. 1072, represents the Earl bearing on his shield a lion. If Snorro Sturleson, the author of the Northern History, is to be credited, Magnus Berfetta, son of Olaf Kyrre, who became King of Norway A. D. 1093, bore, when he invaded Ireland, *gules*, a lion *or*, on his shield and *surcoat*. If this be true, we have here a complete instance of the improved modern Heraldry. The Ist Crusade was proclaimed at the Council of Clermont, A. D. 1095. That this circumstance gave a considerable impulse to the Art is beyond a doubt. One of its principal features was the assumption of a badge, the variation of which has produced a large proportion of Heraldic images. And the intercourse which it opened with the East, the land of symbol and of allegory, contributed necessarily to advance an object which it was, independently, well calculated to serve.

Crusades.

French and Norman Heraldry.

It seems, however, beyond all doubt, that the earliest *proficients* in modern Heraldry were the French and Normans. It is probable that mutual advantages resulted to both nations from the settlement of the latter People in France. The rude system of the Northern warrior became refined and artificial from his intercourse with the courteous cavalier of the South, to whom he in return imparted new materials and new ideas. We do not here speak of national, but of personal emblems: for national Heraldry, in its most proper sense, is of great antiquity. This, therefore, will not be the place to notice the undoubtedly ancient Arms of France, those of Edward the Confessor, and of Normandy, which the Conqueror transferred to the shield of England.

On the seals of the early Norman Monarchs of England their equestrian figures are portrayed; but the interior only of their shields being visible, nothing can be determined as to their Heraldic bearings.[*] This, perhaps, is not of so much moment to the question as is generally supposed: for, if they bore any charge at all, it would, in all probability, be that of Normandy: and the existence of appropriate national devices at that time we shall be enabled to prove beyond a doubt. But " in a splendid illuminated Genealogy of Queen Elizabeth, deduced from Rollo Duke of Normandy, remaining in George III.'s Library presented to the British Museum, King William is represented bearing on his left arm a red shield, charged with two golden lions, and *holding in his right hand a banner, barry of ten, argent and azure.*"[†] " A MS. in the Harleian Library, No. 1073. fol. 6. tells us that the charge on the banner was borne as arms by Fulbert de Faloys (Falaise) his maternal grandfather, and that William himself did bear the same before the Conquest."[‡] If this be true, it settles some important points. 1. That personal Heraldry was in use two generations before William the Conqueror. 2. That it might be hereditary.[§] 3. That it had attained the refinement of ordinaries. Certain it is that the Conqueror's banner, as represented on his seal, bears some resemblance to the barry of Heraldry; but if barry at all, it is barry of six; and thus it is given in Bossewell's *Works of Armorie*, and in the Harleian MS. quoted in the note to Willement's *Regal Heraldry* already noticed: probably on the authority of this identical seal. The device on the seal, however, more nearly resembles three small parallel pennons on one spear than any Heraldic charge whatever. The banner of William Rufus on his seal exhibits what might be called *paly*. For this there certainly appears no assignable reason from what would now be called " Heraldic" considerations. The banner of Stephen exhibits distinctly a cross. The shield of Richard I. is the first which displays lions; but as here we again cross the frontier of *national* Heraldry, we shall repass for the present to take a more general view of *personal*.

Ordinaries, colours, and furs.

For the introduction of ordinaries, colours, and furs, which form so essential a branch of the modern Art, we seem, indisputably, indebted to the ancient Germans. The words of Tacitus, *scuta tantum lectissimis coloribus distinguunt,*[||] are very remarkable. They prove, 1. That the Germans were not in the habit of bearing *devices* on their shields, as these would otherwise have been mentioned; probably through the want of a sufficient know-

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[*] " From the time immediately subsequent to the reign of our first Henry, the fashion was altered; and the persons on horseback represented on the counterpart of seals, appear either as carrying their shields pendent on their breasts, or bearing them on their right arm, so that the convex side of the shield being turned towards the spectator, the charge thereon becomes visible. *The earliest instance of the prevalence of the latter fashion of carrying shields, occurs in an impress of the seal of Stephen, Earl of Richmond, Anno* 1137, *who is there figured holding on his right arm a shield charged with seven fleurs-de-lys.*" Edmondson. This is earlier than the instance adduced by Mr. Gough, the shield of Geoffrey de Magnaville, Earl of Essex, in the Temple Church, who died in 1144.

[†] Willement's *Regal Heraldry*, p. 2. note.

[‡] *Ibid.*

[§] The *Tabula Eliensis*, still preserved at Ely, said to be contemporary with the Conqueror, represents the Norman Chiefs who were quartered on the Monks of Ely, and under each Chief are delineated his *family Arms*. If this Picture could be proved genuine, such testimony would be decisive. But this is more than questionable. Fuller refers it to 1306.

[||] *De Mor. Germ.* vi.

ledge of Art. 2. That they bore on a shield more colours than one: and it is evident that even the most barbarous people would have arranged these colours so as to produce a pleasing effect to the eye, which could only be attained by their distribution into mathematical forms like those now called ordinaries. 3. The word *lectissimis* shows that this distribution and ornament was a choice point with them; which is further confirmed by an assertion immediately preceding, that in other respects they did not affect ornament. Nulla *cultûs jactactio; scuta* tantum *lectissimis coloribus distinguunt.* Whether these colours were selected for their beauty and scarcity, or whether as domestic and personal distinctions, is not easy to say; but selected they certainly were, and selection implies an object and a system. Nor less directly does the testimony of Tacitus indicate the origin of Heraldic furs. *Eligunt feras, et detracta velamina spargunt maculis pellibusque belluarum, quas exterior Oceanus atque ignotum mare gignit.** Here we have, 1. The same circumstance of selection as in the colours;—*eligunt feras.* 2. The origin of all varied furs, as the ermine, ermines, &c. Ernesti, on this passage, explains the *belluæ* to mean *sables,* and interprets *exterior Oceanus, the Countries beyond the Ocean;* somewhat widely. Animals of the seal species are most probably intended. The *sagum* of the Northern nations was the rude sketch of the surcoat; and probably produced ordinaries of its own. The difficulty of procuring an entire dress of the same skin introduced the expedient of disguising necessity by ornament, and thus two or more furs were joined in an ornamental manner, at first simply, afterwards more artificially. Thus, while the *cross,* the *quarterly,* the *gyronny,* the *checky,* the *fretty,* &c. seem to be the most natural divisions of the shield; the *chief,* the *pile,* the divisions called *party,* appear to be those which would most naturally arise from the disposition of furs. The refinement of which we have been speaking introduced the distinctions embattled, engrailed, &c. Indeed, the introduction of furs into the shield at all, probably, arose from the device on the surcoat.

The gradual intermixture, therefore, of the Teutonic nations with those Tribes which had been civilized by the Romans, and the ultimate settlement of the Normans in France, produced, from the combination of military distinctions, the beautiful theory of chivalrous Heraldry, which arose by so nice gradations that it is easier to trace its advancement than to assign its origin; although even the former is not minutely practicable in illiterate Ages. It is remarkable, however, that ordinaries enter little into *national* Heraldry. The chevron does not enter it at all. They are only found in the Arms of small Provinces, which probably adopted those of their Rulers. And this is a powerful, collateral argument in favour of the antiquity of national Heraldry; since we find it so little affected by an introduction which has insinuated itself into almost every family escutcheon.

The reproduction of Heraldry was not instantaneous, nor was its progress uniform. Accelerating circumstances occasionally operated; among which Tournaments and Crusades are justly regarded prominent, although incorrectly assigned as causes where they were simply stimulants. For in that most curious fragment of antiquity, the *Leges Hastiludiales* of Henry the Fowler, we find all persons prohibited from running in the lists who could not prove their "*insignia gentilitia*" for four generations; and violations of these laws are threatened with the forfeit of *insignia gentilitia.* And what these could have been but a kind of family Arms, it is not easy to determine. Of these causes the Crusades are justly considered the most important. For those events created so intimate a connection between the nations of Europe, and so strong an expediency, not to say necessity, for the distinctions of Heraldry, that the intercourse which then arose established the Science on its present basis, and incorporated the local peculiarities of its use into a grand, general, and comprehensive system, which, with very slight variations, and those chiefly very modern, is received throughout the whole of civilized Europe. Although we would scarcely say with Mr. Dallaway, "the feodal system and armorial ensigns are coeval,"* yet that system, which obtained so extensively, had no doubt a great influence in *differencing* Arms. The tenants of a fief would naturally adopt the same Arms with the lord, subject to such differences as should clear them of presumption, or be significant of their fealty.

During the reign of Henry III. Heraldry made rapid progress in England. It was then that Arms became settled and hereditary. The Art had its appropriate devices and vocabulary; and both were nearly as full as at the present day. This is evident from *Les Noms des Chevaliers en le Champ du Roy Henry III.* A. D. 1220, a MS. in the Bodleian Library. To this succeeds the exceedingly curious *Roll of Karlaverock,* lately edited in a sumptuous and accurate manner by Mr. Nicolas. It is a contemporary Work, written in Norman-French verse, and recounts the names and arms of the Knights who attended King Edward I. in his expedition into Scotland, A. D. 1300. The Arms are blazoned with great minuteness and accuracy. By this time the Art was so far reduced to system, that it had distinct Professors, whose duty was not only to be the expositors of its principles, but also to invent and appropriate coat-armours. The long and chivalrous reign of Edward III. and his taste for Tournaments considerably advanced the interests of Heraldry; while the love of dress and exhibitions which characterised his successor, had its influence in enlarging the province of the Art, at the expense, perhaps, of its significance and purity. In the reign of Henry VI. the *Book of St. Albans,* by Juliana Berners, Abbess there, proves that the Art had attained a most considerable refinement.

Heralds

At what time Heraldry first became connected with the officers from whom it derived its name cannot with certainty be determined. The name appears Teutonic: *Herr alt,* aged sir, or lord. It is a translation of the term *veteranus,* a retired soldier, who waited on the Roman Emperors, and was by them employed in messages and negotiations. The office is certainly of very high antiquity. Among the Greeks, Heralds were called κήρυκες. Those of the Athenians affected to be descended from Ceryx, son of Mercury; those of Lacedæmon, from Talthybius, Herald of Menelaus. But the term κήρυξ was indefinitely applied to all. Their duty was to keep order in public deliberations, to bear messages in time of War, to proclaim War and Peace,

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* *De Mor. Germ.* xvii.

* *Inquiry into the Origin and Progress of Heraldry in England,* sec. 1.

Sacrifices and Festivals, and to be present at National Compacts. Their persons were held sacred and inviolable. They are also frequently represented as assisting in dressing the victim for the table in Religious Festivals, and as pouring out the wine on those occasions. Their ensign of office was a sceptre, called *κηρύκιον*, made of laurel or olive, round which two serpents were entwined. Sometimes, however, they bore an olive-branch covered with wool, and adorned with fruits of the earth, called *εἰρεσιώνη*. The *κήρυξ* in the *Agamemnon* of Æschylus is crowned with olive; but this perhaps rather indicates the occasion than the office. To the Greek *κήρυξ* succeeded the Roman *Fetialis*. His duties are laid down in a law quoted by Cicero. (*de Legg*. II. viii.) *Fœderum, pacis, belli, induciarum oratores fetiales judices* duo* *sunto. Bella disceptanto. Prodigia, portenta, ad Etruscos et haruspices, si Senatus jusserit, deferunto.* Some other offices are perhaps assigned them by the same law, which is evidently corrupted. Their office was very ancient. Dionysius refers the institution to Numa; and, considering the general character of this Prince, the reference appears probable. Livy introduces them in the reign of Tullus Hostilius, in the affair of the Horatii and Curiatii, where he narrates, with much solemnity and circumstance, their ceremonies in confirming a national compact. The *Jus Fetiale* attracted the peculiar attention of Ancus, in whose time the Herald declared War by proceeding to the hostile territory, wearing on his head a wreath of wool, and casting over the frontier a spear, or a bloody staff burnt at one end. The Heralds of the Romans were incorporated into a College. Some suppose the *Pater Patratus* to have been a kind of King of Arms; but he rather seems to have been a temporary officer, the acting Herald on public occasions. The same circumstances which first rendered necessary the office of a Herald, perpetuated the appointment to the time of the early Tournaments. Heralds, in those entertainments, were absolutely indispensable for the maintenance of order, the administration of oaths, and the proclamation of the style of the combatants. As the armorial Art became extensive and systematic, a knowledge of its principles became requisite in these functionaries; and, ultimately, as the course of events would lead us to expect, they attained an exclusive control over that which at first they had reverentially studied, and to promulgate authentically the laws of that system of which they had once been the respectful disciples.

The transition from the ancient to the modern functions of the Herald was as insensible as that from ancient to modern Heraldry; and nearly collateral. The Nobility and Knights retained Heralds to proclaim their style, &c. who soon became their authoritative advisers on the subject of armorial distinctions, which, as they increased in influential importance, demanded the especial attention of a professional class. When private individuals granted Arms, Heraldic advice was indispensable. Hence came too the distinction of Pursuivants, or Probationers for the Heraldic office; a distinction which still continues to obtain. But it is in the reign of Edward III. that we find the first positive evidence of their regular recognition by Government. That Prince created two Kings of Arms, Surroy and Norroy, who took cognizance of Heraldic matters to the South and North of the Trent respectively.* Richard II. laid the first foundation of a College of Arms, by giving the Earl Marshal power to preside in the Court of Chivalry, and to summon the Heralds to his assistance. The Heralds there appeared as advocates, having analogy to Barristers, as the Kings of Arms might be said to have to Serjeants at Law, and the Pursuivants to Law Students. The nature of the causes tried in this Court, mostly referring to armorial bearings, at once settled and enriched the system. But the first regular Collegiate Heraldic Chapter was held at the siege of Rouen, A. D. 1420. From that time the Heralds became a Corporate Body, having their statutes and observances; and it remained only for Richard III. to establish them in a permanent abode in London, and to give their institution the seal of his patronage and authority. They had already been incorporated in France by Charles VI. A. D. 1406.

College of Arms.

Although, on account of their natural attachment to their benefactor, the Heralds suffered in the reign of Henry VII., and were expelled from their College, the office was not on that account disrespected; on the contrary, that Monarch constantly retained about him one individual of each Heraldic Order. But the Kings of Arms were reduced to three, their present number. Henry VIII. augmented the revenues and privileges of the Heralds, and during his reign we find them continually employed in public duties and negotiations. This Prince was partial to Heraldic honours, as little costly to the Sovereign, and, in those days of chivalrous sentiment, often more satisfactory to the wearer than more solid distinctions. From this reign we may *chiefly* date the custom of honourable augmentation, which, while it has rendered the Art more complex, has diminished its distinctness and peculiarity.

Heraldic Visitations.

Heraldic Visitations of Counties, with a view to collect information with respect to genealogies and hereditary coat-armour, had occasionally taken place from the time of Henry IV. But in 1528 a regular Commission was granted for a general Visitation of the whole Kingdom; and from that time till the early part of the XVIIIth century, the practice was renewed every twenty or thirty years. This circumstance had an important influence on Heraldry. Every wealthy person was ashamed to have his genealogy recorded without appendent coat-armour; and those symbols, which had formerly been the exclusive guerdon of knightly prowess, were now at the purchase of merchandise and trade. Hence were introduced a number of devices unconnected with the Science, and not always strictly harmonizing with its spirit, but significant of the origin and occupation of their wearers. Yet there can be no doubt that much irregularity was hereby removed; although the rules to which practice was ordinarily recalled, differed in principle from those of purer Ages. The intercourse also which the European nations in general now began to maintain with Italy, and which so powerfully affected the interests of Art, could not be without operation on the kindred pursuits of Heraldry; an operation which, however advantageous to the *graphic* province of the study, was highly prejudicial to the theory, which it adulterated and defaced with incongruous emblems.

Edward VI. reinstated the Heralds in an establish-

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* This reading is very uncertain, and, as we think, improbable.

* The whole History of Kings of Arms is involved in much obscurity: even this fact respecting them, which is one of the clearest, has been controverted.

quity. The necessity of some distinguishing ensign in war appears to have suggested the use of these symbols, by which the valour, policy, or tutelary divinity of a State were in turn typified. The goat, which is made by Daniel[*] the emblem of the Macedonian Empire, was, it appears, the sign depicted on the Standard of that people, or, as we should now speak, the Arms of Macedonia. Justin, the abbreviator of Trogus Pompeius, informs us that Carenus, founder of the Empire of Macedon, when hesitating where to build his city, was commanded by an Oracle to observe the track of some goats:[†] and in commemoration of that circumstance, he adopted the goat as the Device of his new settlement. The ancient Standard of Persia was, as we learn from Xenophon, an eagle displayed on a shield.[‡] Whether the Device were sculptured in relief on the shield after the *Heraldic* fashion, or represented as standing upon it, is not quite clear. This eagle was the Royal Badge of Persia from the time of Cyrus the Great[§] to that of Artaxerxes Longimanus; perhaps longer. An eagle was also the *Arms* (if we may so speak) of Rome. The owl, the bird consecrated to Minerva, tutelary Goddess of Athens, was the adopted emblem of that State, and appears on the Athenian coins and medals. Corinth bore a Pegasus; Tyre, a palm tree; Antioch, a ram and a star; Nicomedia, a trireme and two turrets; Chios, a Sphinx. Further enumeration is unnecessary. But the universal prevalence of National Heraldry is evident from this circumstance, that the Turks and Persians, who have no personal Heraldry, as the Art is at present understood, possess what may be most strictly termed National Arms: those of the Turkish Empire being, in terms of modern blazonry, *azure*, an increscent *argent;* and those of Persia, *argent*, a sun orient, *proper*, behind a lion couchant, *or*. But the flags of these nations differ; for the Turkish flag is *vert*, three increscents *argent*, and the Persian, *or*, three decrescents *argent*. The crescent has been probably derived to the Turks from their Scythian ancestors; but the ancient bearing of Byzantium was a crescent. Many are of opinion that the *lunatæ peltæ*, ascribed by Virgil[||] to the Amazons, were charged with crescents; but it is very possible they were rather made in that form.

We may have appeared to some readers to have transgressed the laws of just arrangement, in employing terms of Art without a previous definition of them. But, as the History of our subject seems entitled to consideration before we enter on its detail and application, we are sometimes compelled to forestal information which the reader, if he does not already possess it, must seek under our definitions.

History of the Arms of France,

The Arms of France are undoubtedly of great antiquity. We have seen what evidence there is for their existence during the Merovingian and Carlovingian dynasties. They were, certainly, the same Device thrice repeated; although what that Device originally was, cannot be determined. The discordance of opinions on this subject, however, is evidence of the early use of these Arms. And this belief derives confirmation from a similar discordance on the subject of their *colours;* a circumstance, we know, indifferent in ancient Heraldry, but in modern integral and essential. Paulus Emilius blazons the Arms of France, *argent*, three diadems, *gules;*[*] "others say they bear three toads *sable* in a field *vert;*"[†] which, if ever they did, it must have been before the existence of the present rules; as this would now be false Heraldry, for reasons which will be hereafter specified. M. de Foncemagne, in a Treatise on this subject in the *Mémoires de l'Académie des Inscriptions*, vol. xx. cites, beside the above opinions, other testimonies, respectively stating that the Arms of France were crescents, water-flags, bees, lilies, and spear-heads. The *fleur-de-lys* became the settled Arms of France in the reign of Louis VII.: it is said that they are the flowers which grow on the sides of the river Lys, (*Iris pseudacorus*, Linn.) which separated Artois and France from Flanders after the marriage of Philip Augustus with Isabella of Hainault. But it is somewhat curious that when the *nature* of the devices became determinate, their number, which had ever been constant, became indefinite. In the reign of our Richard II., however, we find them borne generally, *azure*, three fleurs-de-lys, *or*, a change effected by Charles VI., but not always attended to subsequently. There is an ingenious argument used to prove the *fleur-de-lys* a lily, which may find credit with such as are not sufficiently incredulous to disbelieve the Salic constitutions. The motto of France is *Neque laborant neque nent;* in allusion, of course, to lilies; which lilies, *of course also*, must have been adopted to typify the impossibility of female sway in France!

National Heraldry,

Mecklenburg,

The Arms of Mecklenburg claim even an earlier origin, and, considering the undoubted use of Devices of this kind by ancient States, and the similar original of many, the legend concerning them is not improbable. We are told that Artyrius, King of the Heruli, having started as a soldier of fortune under Alexander of Macedon, sailed in a ship bearing for its device, or sign, a bull's head; and that, ultimately, settling in the States of Mecklenburg, he assumed this as his cognizance. Hence the Arms of Mecklenburg are at present, *or*, a bull's head *gardant*, *sable*, horned and ringed through the nose *argent*, and ducally crowned *gules*. We may observe, that these are also the Arms of Rostock, except that the bull is not *gardant*.

Germany, Poland, and Russia.

A like traditional legend obtains concerning the Arms of Russia, Germany, and Poland, the last now lost, the second merged in those of Austria. It is said that the eagles taken from the three legions of Varus destroyed by the Germans, fell respectively into the hands of the native Germans and their Sarmatian and Sclavonian auxiliaries; which nations, accordingly, adopted each of them an eagle for their ensign.[‡]

England.

The Arms of England reach beyond any assignable date after the conversion of the Saxons. Each Heptarchy is supposed to have had its peculiar ensign; but the most prevalent was a cross, used probably in commemoration of their conversion. To this cross, Edgar

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[*] *Dan.* ch. viii. ver. 5.

[†] Just. vii. 1.

[‡] *τὸ βασίλειον σημεῖον ὁρᾶν ἔφασαν, ἀετόν τινα χρυσοῦν ἐπὶ πέλτης, ἐπὶ ξύλου ἀνατεταμένον.* De Cyri *Exped.* lib. i. *sub finem.*

[§] *ἦν δ' αὐτῷ τὸ σημεῖον ἀετὸς χρυσοῦς ἐπὶ δόρατος μακροῦ ἀνατεταμένος. καὶ νῦν δὲ ἔτι τοῦτο τὸ σημεῖον τῷ Περσῶν βασιλεῖ διαμένει.* De Cyri *Instit.* lib. vii. *circa init.*

[||] *Æn.* I. 490. and xi. 660.

[*] *Ap.* Gwillim, ch. i.

[†] *Ibid.*

[‡] Cuspinian's version of the story somewhat differs. *Tres legiones obtruncatæ, signa, et aquilæ duæ a Germanis raptæ, quas hodiè possidemus. Non enim biceps est aquila, quod imperitum vulgus credit; sed duæ simul, quarum altera alteram expansis alis obtegit. Tertiam signifer legionis III. abstulit, paludeque demersit, ne in hostium manus veniret. Alioqui III. haberemus aquilas in insignibus imperii. Vit. August*

is said to have added four martlets, and Edward the Confessor one. The Arms were blazoned in the time of Richard II., (who impaled them with the then received Arms of England,) *azure*, a cross *flory*, between five martlets, *or*. These Arms were never used by the Norman Princes, and rarely by succeeding Sovereigns, never without the Arms of Normandy, which were now become those of England. Yet they were not allowed to be borne by a subject; witness the Trials of Thomas Duke of Norfolk, and his son Henry Earl of Surrey, in the reign of Henry VIII., for High Treason, where a principal part of the accusation was the assumption of these Arms.

The lion and the cross are very prevalent in National Heraldry, and this interesting portion of Heraldic History will derive considerable light from the explanation of those symbols. The former was naturally adopted in a rude state of Society, where courage and military superiority are always the first, if not the only, virtues. The latter as naturally became the favourite Device of those nations who had been recently converted to Christianity or had distinguished themselves in the Holy wars. Constantine set the example by mingling his *labarum* with the eagles of Julius and Augustus. The fanciful varieties, both in number and position, which we find in these emblems, are to be attributed to the necessity of international distinctions. And the same may be said of colour, when this circumstance came to hold an essential office in the shield. When, in the Crusades, the armies of whole nations bore the cross, it was necessary to distinguish them by some variation of form or colour, and this, we know, did accordingly take place. This remark on lions and crosses will explain the origin of many national Arms without further observation; as those of Scotland,* of Normandy, afterwards adopted for England, of the late Republic of Venice, of the Republic of Geneva, of Denmark, of Norway, of Sardinia, besides a variety of inferior States. Crowns and swords, for a similar reason, would naturally be favourite emblems, as the ensigns of power and force; and their positions, numbers, and colours would be affected by the same circumstances as other devices. Hence we may explain the Arms of Sweden, of Saxony, and several others. It is curious that all these emblems (with the very natural exception of the sword) are to be found in the Arms of the Universities of Cambridge and Oxford. The cross, Gospel, and lions in the former are significant of boldly contending for the Faith; the crowns and Psalter in the latter have a like allusion to the supremacy of Religion.

land.

Three principal *Devices* have been assigned for Ireland; all, doubtless, of high antiquity. A harp, a shamrock, and a hart issuant from a castle. The first of these has been retained as the Arms, the last is sometimes used as the crest. The second appears in the Badges of the Order of St. Patrick. The adoption of the two former may be easily explained from national characteristics; the latter is not so easily accounted for. Other Arms have been assigned for Ireland; for which see a very comprehensive note in Willement's *Regal Heraldry*, p. 81.

Leon. Castile, and the United Provinces.

National Arms are, in some instances, like personal, expressions of a name. Thus the lions of Leon and the castles of Castile are evidently mere pictured words. But the Arms of the United Provinces are, perhaps, the most eloquent of all, wherein a lion grasps in his paw seven arrows. The allusion is too obvious and beautiful to need explanation.

III. *Arms of Bodies Corporate.*

The origin and history of the Arms of Bodies Corporate very much resemble those of nations, as nations are only larger Societies. Crosses, lions, swords, and crowns abound in all. Some represent the character of the Society, as those of Guilds and Companies. Some the local situation, as those of Cities; some have an affinity with the name; and some are honourable grants. The dagger in the Arms of the City of London is of the latter nature, being added in honour of Sir William of Walworth, Lord Mayor, who killed the rebel Tyler. The Arms of the Cinque Ports afford a curious combination: lions terminating in ships; thus uniting a favourite with a significant device, and implying, apparently, that the strength of that confederacy is in its shipping.

Principles of the System.

Such is the History of that curious and interesting theory, the present refined principles of which we proceed to deliver. These may be divided into I. *Blazonry*, and II. *Marshalling*.

I. Blazonry.

I. *Blazonry* is the art of expressing in due and significant language, a coat of Arms, so that its colours and forms may be as obvious in description as in actual delineation.

Although the terms "*coat* of Arms," and "*coat* armour," are commonly applied by Heralds to personal and family Devices, from the circumstance of these being embroidered on the surcoat, or covering of the armour, yet as the same were also depicted on the shield, on which they could be more evidently exhibited, the shield has always been selected as the most convenient vehicle of the Arms; and the form of the shield usually adopted is a modification of that which was used by the Normans. Fig. 1 is the true Norman shield; the others are the modification of which we speak, ordinarily in use in the times of the Lancaster and York dynasties, and more convenient, on the score of amplitude, for the exhibition of Arms.

Points of the shield.

Every shield has its distinguishing *points*; and as the shield never varies so considerably as to render their positions importantly different, fig. 1 will afford a clear notion of the theory. "In the enthusiastic Ages of Chivalry, every object which related to the profession of arms was exalted and dignified. The armour was so closely united with the body, that it seemed to make a part of it; and an insult offered to it would have been resented with as much warmth of revenge as if the warrior himself had been treacherously wounded. Hence it arose that the shield was considered as the man himself; and its parts were denominated accordingly."* Thus the side towards the left hand is called the *dexter* side, and that towards the right hand the *sinister* side. The upper part is called the *chief* (*chef*, head.) The points in the chief are A, *dex-*

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* The treasure flory is said to have been added to the Arms of Scotland by Charlemagne, on the occasion of his League with Achaïus. The sentiment symbolized by this addition was, that the lilies of France should always protect the lion of Scotland. It is unnecessary to insist *much* on the exact degree of credibility which belongs to this story; but it affords no bad idea of the significance of Heraldic emblems.

* *Encyc. Lond.* Art. *Heraldry.*

ter chief; B, *middle chief;* C, *sinister chief;* D is the *honour point,* representing the breast by its highest chivalrous virtue; E is called the *fess point,* bisecting the straight line which joins the middle chief and extremity of the shield. It is so called from the *fess,* which it also bisects, and which represents the scarf or belt (*fascia*) worn round the middle; F is the *nombril* (navel) *point;* G, the *dexter base;* H, the *middle base;* and I, the *sinister base.*

Field. Having determined the points of the escutcheon, the student's next care is to determine the *field,* by which name Heralds designate the tincture or combination of tinctures forming the ground on which the Device is delineated. These are of three descriptions, *metals, colours,* and *furs.* They are all equally expressed by colours in painting; but in engraving and sculpture, an ingenious mode of distinguishing them was invented by Silvestro di Santa Petra, an author of the XVIIth century, by the position of lines, which is now universally adopted.

Metals. Or. Fig. 2 exhibits the metals. That on the dexter side is *Or,* (Fr. *or,*) gold. It is represented in colouring by liquid gold, gamboge, chrome, or king's yellow; shading, burnt sienna: in engraving by a sprinkling of equidistant dots. *Or* alone is said to have been formerly the Arms of Arragon. That on the dexter side is

Argent. *argent,* (Fr. *argent,* silver,) expressed in colouring by a white, and in engraving and sculpture by a plain surface. Shading, Indian ink or lamp black.

Colours. Fig. 3 is an escutcheon containing the *colours.* Du Cange is of opinion, that all the tinctures were originally furs;* and though this belief has met with little countenance from modern Heralds, much may be said in its favour. From what has been cited from Tacitus, it appears that the Northern warriors used garments of fur; and the surcoat often supplied a field to the escutcheon. Besides, those shields which were not composed of metal were generally covered with skins; and even those which were so, had, not unfrequently, a guarding of the same material. In our enumeration, therefore, of the tinctures we should deem it unjust to the question to suppress what may be advanced in support of this opinion.

Gules. No. 1 is *gules,* red, expressed in colouring by vermilion; shading, lake; in engraving by vertical lines. It is generally derived from the French *gueule,* the mouth of an animal. But Du Cange assigns a much more probable etymology. He quotes from St. Bernard (*Ep.* 42.) the following passage, *Horreant et murium rubricatas pelliculas, quas* Gulas *vocant, manibus circumdare sacratis.* And Brunon, a still earlier writer, thus mentions these sorts of furs in his *History of the War of Saxony:*† *Unus ex illis cujusdam nobilis crusinam* gulis *ornatam quasi furtim præcidit. Crusina* is a Saxon word for a fur dress. Somner, in his *Glossary,* gives *Crusene, tunica e ferinis pellibus.* Le Reclus de Molieus, in his MS. *Paternoster,* has these lines:

Houches, manteaux, chappes fourrées,
De Sobelines engoulées.

From these authorities the derivation of the word *gules* is tolerably clear; and scarcely less clear is it that the gules was originally a fur. According to Gwillim, Eumenius de la Brect, a Knight who accompanied Edward I. in his Scottish expedition, bore this colour alone as his Arms.

Azure. No. 2 is *azure,* sky blue, from the French *azur,* represented in colours by verditer, smalt, or ultramarine; shading, indigo; and in engraving by horizontal lines.

Sable. No. 3 is *sable,* black, expressed in colouring by lamp or ivory black; shading, same with gum; and in engraving by vertical and horizontal lines. It is commonly derived from the French *sable,* gravel; but the inapplicability of the derivation has been evident to those who have made and approved it. It seems almost obvious that this tincture was originally the fur of the sable. And to this effect is the express testimony of Spelman. (*Aspilog.* p. 76.) *Sæpenumerò pelles quædam quibus alias ad honorem et insignia induebantur proceres,* colorem *clypeis subministrant, armellinorum et* zebellinorum.

Vert. No. 4 is *vert,* green, (Fr. *verd,* anciently *vert,*) expressed in colouring by a mixture of verditer and gamboge; shading, gamboge and indigo; and in engraving by diagonal lines from the dexter to the sinister side of the escutcheon.

Purpure. No. 5 is *purpure,* from the French *pourpre,* purple, expressed in colouring by royal purple; shading, same with gum; and in engraving by diagonal lines from the sinister to the dexter side of the escutcheon. This colour so seldom enters coats that some Heralds have denied it a place among the Heraldic tinctures. This circumstance Du Cange attributes to its derivation from a fur called *pourpre,* of a coarse and humble kind, and seldom worn by Knights or distinguished persons.

Sanguine. No. 6 is *murry,* or *sanguine,* a colour scarcely ever used in England, but occasionally met with in foreign Arms, and by some ascribed to the Arms of Wales. It is a dark red, expressed in engraving by opposite diagonal lines, and is reckoned one of the *stained* or dishonourable colours; as is also

Tenny. No. 7, *tenny, tawny,* or *brusk,* a colour compounded of red and yellow, and expressed in engraving by diagonal and horizontal lines.

These are the usual terms of the Heraldic colours. But invention, which is the very essence of this theory, has not limited itself to these. The annexed Table, borrowed from the very valuable Essay on this subject in the *Encyclopædia Londinensis,* is a comprehensive view of the various denominations by which the Heraldic colours have been blazoned.

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* First Dissertation on Joinville's *Chronicle.*

† *Rer. German. Freher,* tom. i. p. 135.

Names.	Colours.	Stones	Planets.	Planets.	Metals	Latin Names.	Abbreviations.	Signs of the Zodiac.	Months.	Days of Week.	Elements.	Seasons and Time of Day.	Ages.	Tempers.	Virtues.	Flowers.	Numb.
OR.	Yellow	Topaz	Sol.	☉	Gold.	Aureus.	O.	Leo.	July.	Sunday	Light.	Noon.	Adolescence.	Blithe.	Fortitude.	Heliotrope.	1.3
ARGENT.	White.	Pearl.	Luna.	☽	Silver.	Argentus	Ar.	Cancer.	June.	Monday.	Water.	Morning	Infancy.	Phlegmatic.	Hope.	Lily.	2.12
GULES.	Red.	Ruby.	Mars.	♂	Iron.	Ruber.	*g.*	Aries and Scorpio.	March and October.	Tuesday	Fire.	Autumn.	Manhood.	Choleric.	Charity.	Rose.	10
AZURE.	Blue.	Sapphire.	Jupiter.	♃	Tin.	Cæruleus.	Az.-b.	Taurus and Libra.	April and September.	Thursday.	Air.	Summer.	Childhood.	Sanguine	Justice.	Blue Bell	4.9
VERT.	Green.	Emerald.	Venus.	♀	Copper.	Viridis.	Vt.	Gemini and Virgo.	May and August.	Friday.	Life.	Spring.	Youth.	Bilious.	Strength.	The Field	6.11
PURPURE.	Purple	Amethyst.	Mercury.	☿	Quicksilver.	Purpureus.	Pur.	Sagittarius and Pisces.	November and February.	Wednesday.	Thunderbolt.	Evening.	Old Age.	Serious.	Temperance.	Iris.	7
SABLE.	Black.	Diamond.	Saturn	♄	Lead.	Niger.	S.	Capricorn and Aquarius	December and January.	Saturday.	Earth.	Winter and Night.	Decrepitude.	Melancholy.	Prudence.	Scabiosa	5.8

None of these are in any credit except the Planets and Jewels; the former being attributed to the coat-armour of Princes, the latter to that of the Nobility. But even this practice is by no means general, and is not sanctioned by the adoption of the College of Arms. In the coats of traitors or defamed persons, it is usual to blazon by the natural metals and colours, as gold, silver, red, &c.

urs. rmino. Figures 4 and 5 contain the furs. No. 1 is *ermine.* It represents the skin of that animal, (*Mus Armenius,*) which is perfectly white,* spotted with tails of the same creature, which are black. The ermine is a fur of great dignity, being generally used in the robes of Royalty and Nobility. Its beauty and rarity have procured it high estimation; and some writers consider it an emblem of purity, the ermine being reported to prefer death to soiling its delicate fur. Each row of spots is Heraldically termed a *timber*, and the lower parts of spots are termed *muschetors*. Ermine alone is the coat-armour of the Dukedom of Brittany.

mines. No. 2 is called *ermines*. It is the inversion of ermine. Here the fur is black spotted with white. The exact application of the word is not clear.

an. No. 3 is *pean*. It resembles the last, except that for white we have gold. The word is perhaps derived from the French *paon*, a Peacock, the glitter of whose plumage it somewhat resembles.

minois. No. 4 is *erminois*. It is the same as the ermine, except that the white is exchanged for gold. It signifies erminelike, a character which it aptly sustains.

ir. No. 5 is *vair*. It is always white and blue, unless otherwise specified in blazon. The pattern, somewhat resembling wine glasses, has led some etymologists to derive the term from the French *verre;* but it is much more probably derived from the Latin *varius*. It is supposed to represent the skin of a small spotted squirrel. Vair of gold and blue is the coat armour of the French family of De Rochfort, and vair of ermine and red is that of the Greslies of Derbyshire. Beffroy. A large kind of vair is by some Heralds called *beffroy*, and the family of Bauffremont bears beffroy gold and red. Counter-vair. When the cups are set point to point, as in No. 8, the bearing is called *Counter-vair.*

Potency. No. 6 represents a fur to which many names have been given, *vairy cuppy, vairy tassy, meire, potent-counterpotent*, and *potency*. *Vairy* appears to be derived through *varié* from *variatus*, as *vair* from *varius*. *Cuppy* and *tassy* are from the French *coupe* and *tasse*, each word signifying a cup, which the pattern very slenderly imitates. The original of *meire* is not so plain. *Potent* is the old name for a crutch, on account of the *power* which it gives to its owner; and certainly the pattern of this fur very much resembles the heads of crutches.

Erminites No. 7 is *erminites*, a fur only differing from ermine in respect of the side hairs of the timberings, which are red instead of black.

Vairy. When more colours than two are combined in the pattern of vair, then results the fur called vairy. It is derived from the French *varié*. It is said that ancient Heralds made no distinction between vair and vairy, but blazoned them both vair, and then enumerated the colours. Whenever the distinction arose, it was certainly beneficial, as it simplified the language of blazonry by a very pertinent discrimination. When the colours are white, red, gold, and black, it will suffice to blazon vairy only; where they differ from this arrangement, the difference must be specified. But this fur is very unusual.

These are the only names applied to *fields;* except those compound coats, &c., which will hereafter be noticed. Natural objects, in addition to these, are denominated *proper*, when they are represented in the colours which belong to them; the same is the case with chimerical objects when represented in conventional colours.

Charge. After the statement of the field, the next point of blazonry is the definition of the *charge*, or object delineated on the field. All the stores of Science, Nature, and Imagination have been laid under contribution to furnish forth this department of the Art. We shall not, however, imitate

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* We say white, black, &c., not *argent, sable*, &c., as we observe to have been done by some approved writers; for we are now discussing the subject of furs, which cannot be composed of metals or colours. Even Gwillim, who has occasionally fallen into this unheraldlike practice, has himself condemned it, speaking of the white lining of mantlings:—"Being a doubling, it is no offence, saith Christine de Pia, to call it *white*, because therein it is to be understood onely as a furre of skin." cap. iv. sec. 1.

Counter-changed.

Adumbrated.

some writers on this subject, who crowd their Works with the blazon of a great number of charges, unnecessary, because untechnical. Many charges must be obvious, as soon as mentioned, to the mere unheraldic reader, because they are unconnected with the language of the Art. Thus it would be unnecessary to notice the Arms of Milveton, which are *azure*, three millstones *argent*, enough having been already said to make such coat-armour as perfectly apparent to the mind, as its representation could make it to the eye. We shall prefer to confine ourselves to such charges as are either strictly the production and property of Heraldry, or which have become connected with its language from the mode of their position on the escutcheon. It is to be observed, in respect of charges in general, that metal must never be laid upon metal, colour upon colour, or fur upon fur. Thus *azure*, a swan *gules*, would be false armoury. This rule is not entirely without exceptions, but they are so few, or so slightly authenticated, that they do not affect its general validity. But if the Heraldic colour of a charge be *proper*, then it may be laid on a homogeneous metal or tincture. Thus *sable*, a heart *proper*, is admissible, (see fig. 21,) though the proper colour of the heart be the same with the Heraldic *gules*. But though not unclassical, such instances are rare. Charges are said to be *counterchanged* when the field is of two metals or tinctures, and the parts of the charge are of the opposite metal or tincture. And they are said to be *umbrated* or *adumbrated*, when they are simply shaded on the field without any difference of colour.*

When the field is *gritty*, *i. e.* contains equal proportions of metal and tincture, the charge may be of either; and, in all cases, if a charge intervene between any point of the field and any point of another charge, the latter may be homogeneous with the field.

In colouring, the sides and base of the shield are generally supposed to lie in the plane of the paper, and the middle chief somewhat above it. The charge is supposed to be in high relief, with the light falling from the dexter chief. In blazoning, the field is mentioned first, afterwards the charge. Sometimes a charge itself is charged: in which case the charge nearest the field should be mentioned first. But where several charges lie in the same plane, they must be mentioned in the most compendious order, whatever that may be; for conciseness is a very material quality in blazonry. *Cæteris paribus*, the charge nearest the fess point should be mentioned first. "You must use no iteration," (says Gwillim,) "or repetition of words in blazoning of one coat, especially of any of these four words, *viz. of, or, and, with*. For the doubling of any of these is counted a great fault, insomuch as the offender herein is deemed unworthy to blazon a coat armour." Despite the anathema of this venerable authority, it will not always be possible to preserve this rule consistently with perspicuity. But it may serve for general observation.

ORDINARIES.

The simplest description of Heraldic charges are the ordinaries. An *ordinary* is a portion of the escutcheon comprised within straight or other lines. It should comprise at least one-fifth of the whole shield: otherwise it would be called a *subordinary*. But this distinction is neither very generally employed, very regularly defined, nor very intrinsically important. Beside the straight line, most usually employed as the boundary of the ordinary, the following deviations are in use.

XII. *Ingrailed*, from the French *engrêler*, from *grêle*, hail. It represents the notches made by hailstones.

XIII. *Invected*, the reverse of ingrailed. *Ab invehendo; quòd* invehuntur *puncta figuræ*.

XIV. *Wavy*, or *Undy*, representing the surface of the sea. If the ordinary has two sides the elevations and depressions are alternately opposite: which rule holds in most of these variations.

XV. *Nebuly*, from the Latin *nebula*, a cloud, which this variation somewhat resembles.

XVI. *Raguly*, (ragged, or rugged,) imitative of the trunk of a tree with its branches lopped. A tree so represented is said in Heraldry to be *raguled*.

XVII. *Rayonny*, from the French *rayon*, a ray.

XVIII. *Indented*, from *in*, and *dens*, a tooth. It resembles closely the teeth of a saw. It is also called *enrased*, *viury*, *lentally*, and *serrated*.

XIX. *Dancetty* is a row of points, arranged like those in *indented*, but larger, and never exceeding three. Its derivation is the same as the former, but through the French *denché*.

XX. *Embattled*, or *Crenelly*, representing the battlements of a fortress. The French verb *creneler* signifies to notch, or embattle. When the battlements are alternate to each other, the ordinary is said to be *counter-embattled;* when opposite, it is called *bretessed*, (buttressed.)

XXI. *Battled embattled* is where one row of battlements stands on another.

XXII. *Palissy*, or *Urdy*, is an imitation of the *palisading* of a trench.

XXIII. *Angled* is the same as *embattled*, but on a larger scale. It presents only one right angle.

XXIV. *Bevelled* differs from *angled* in the direction of the angle, which is *acute*.

XXV. *Escartely* differs from angled by presenting only one rampart instead of one angle.

XXVI. *Nowy*, (*nœué*,) composed of knots. This variation is very seldom used.

XXVII. *Dovetail*, a term which is self-expressive.

XXVIII. *Potency*, a series of crutch heads. The meaning of the term has been already explained.

When an ordinary has two sides, and is only variated on one, if that one be the upper side, the ordinary is said to be *superingrailed*, *superinvected*, &c.; but if it be the under, then it is said to be *subingrailed*, *subinvected*, &c. If the ordinary be *generally* curved, it is said to be *arrondy*, (*arrondi*, rounded, Fr.) or *archy;* if one side of the ordinary be curved inward, it is called *invex*, *concave*, or *champain;* when outward, *chapourned*, or *convex*.

Pale.

The first and simplest ordinary appears to be the *pale*. This ordinary is bounded by two vertical lines, at equal distances from the sides of the escutcheon, of which it encloses one-third. When it is charged, the practice is to make it a little wider; but Gwillim condemns the theory: "the content of the Pale must not be inlarged, whether it be charged or not."* It seldom bears more than three charges. The word is obviously derived from

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* "There be certan nobuls and gentilmen in Englonde the wich bere shadys diverse in theyr arms, as lyon, antlop and other. And men say that suche personys as beere theyr umbrated armys had there progenitoris beryng the same not umbrated but hole. But the possessionis and the patrimonys descendid to other men. Then the nevoys or kynsmen levyng in goode hoope and trustyng to have the possessious of their progenitoris, beer their arms umbrated, all oler differs aforesaid leving."—*Book of St. Albans.*

* *Display*, ch. v. sec. 2.

palŭs, a stake, (whence *palisade*,) which the ordinary entirely resembles. *Palūs*, a marsh, and the *pallium* of the Priest, it in no respect accords with. The motto which accompanies the arms of Beauvais in Picardy, (Fig. 6 exemplifying the Pale,) "Palus *ut hic semper constans et firma manebo*," seems to be quite decisive.

let. The diminutives of the pale are the *pallet* (*pallette*, small pale, Fr.) and the *endorse*. The pallet is one-half of the pale, when borne by itself; sometimes, however, as many as three pallets are borne on the shield; when the content of the ordinary is, of course, diminished. Of this we have an example in fig. 7. *Or*, three pallets wavy, *gules*, for the City of Mechlin.

lorse. The *endorse*, or *verget*, contains one-eighth of the pale. The most usual bearing of this ordinary is together with the pale, an endorse being on each side. And this is evidently the derivation of the word, (*in dorso*,) implying that the pale is *backed* by the endorses. Leigh affirms, indeed, that the endorse cannot be otherwise borne; for which he is reprehended by Ferne, who adduces the example of the Arms of Flanders and Tyrol, borne in the Arms of Philip, husband of our Mary I. But as these Arms are painted on a window of the library at Lambeth Palace, they contain no endorse at all. We shall give an instance of an endorse borne singly. The pallet and endorse are never charged. They are seldom composed of furs, and never of vair. Fig. 8 is the Arms of Bellasius, a Norman Chief, sent by William I. to conquer the Isle of Ely. From him the Bellasis family descend, and quarter his Arms with their more recent bearings. The Arms are blazoned, *argent*, *a pale engrailed*, endorsed, *sable*.

Fig. 9 is an instance of the endorse singly borne, and is besides a rare and curious piece of blazonry. It represents the Arms of Sublet de Noyers, a French family. *Azure*, on a pale walled *argent*, an endorse *sable*.

r. From this ordinary is derived the term *paly*, applied to vertical equidistant lines, the spaces between being filled with alternate heterogeneous tinctures. The metal usually takes precedence, although this is not uniformly the case. The several spaces are called *pieces*, and the coat is denominated from the number of *pieces*. Fig. 10 is paly of eight pieces, (or, as it is sometimes expressed, paly of eight,) *or* and *gules*, for the Kingdom of Arragon. All the divisions are supposed to lie in the plane of the escutcheon, and must not, therefore, be shaded.

y per When a coat is bisected by a vertical line, and the fields comprised in the halves differ, it is said to be *party* (*parti*, Fr. divided) *per pale*; or simply, *per pale*; thus fig. 2 is *party per pale*, (or, *per pale*,) *or* and *argent*. This bearing was anciently called *bebally*. It is to be observed, however, that "partys" seldom consist of homogeneous tinctures, *viz*. colour and colour, metal and metal, &c.; ermine and ermines are sometimes found. And if each division comprise a separate coat, **le-** the coats are said to be *impaled*. In both cases the plane is supposed to be the same. Party per pale, *argent* and *gules*, is the bearing of Waldegrave.

rise. When any charge of greater length than breadth lies in the direction of the *pale*, it is said to lie *in pale*, *palewise*, or *paleways*. Thus fig. 11, the Arms of the championship of England, are blazoned, *argent*, a sword *sable*, erect *palewise*. And the same term is applied to any number of charges not very long, in the same field, arranged in the direction of the pale. The Arms of the See of Bristol (fig. 12) are *sable*, three crowns palewise, *or*.

Fess. The derivation of the *fess* (*fascia*) has been already alluded to. It represents a military belt or girdle passing straight round the middle of the body. It is bounded by two horizontal lines, equally distant from the *fess point*, or centre of the escutcheon, of which it contains one-third. *Gules*, a fess *argent*, (fig. 13,) are the Arms of the Electorate of Austria. The fess is sometimes *couped*, (*coupé*, Fr. cut,) not reaching to the sides of the escutcheon, as in fig. 14, the Arms of the family of Stratford. *Gules*, a fess couped, *or*, between three trestles, *proper*. This is also called a fess *humetty*. When more than one is borne in a shield, they are termed *copper cakes*.

Bar. The diminutives of the fess are the *bar*, the *closet*, and the *barulet*. The first of these contains the fifth part of the field. If there be but one of these in the escutcheon, it must occupy the place of the fess; if two, they must be so placed that the field may be exactly divided into five equal parts, as in fig. 15, the Arms of Harcourt, *gules*, two bars, *or*. The derivation of the word *bar* is obvious.

Closet. The *closet* contains half the bar. It appears to be derived from *claudo*, to shut, and to represent a bar used to shut or close gates or doors. (*claustrum*.) Five closets may be used in one field. Or, perhaps, from the fess being sometimes *enclosed* by two of them, *quòd* claudunt *latus fasciæ*. Fig. 16, *azure*, four closets, *or*, is the Arms of the city of Salisbury.

Barulet. The *barulet* contains one-fourth of the bar. It is generally used with the fess, one on each side of that ordinary, in which case the fess is said to be *cotised*. Some restrict this office to the closet, and, perhaps, more properly. The derivation of the term *cotise* will be given presently. Sometimes they are found in groups of two each, when they are called *bars gemelles*, and the two are reckoned one bar. Fig. 17 exhibits this ordinary in the Arms of Barry, of which family is Lord Barrymore, *viz*. *argent*, three bars gemelles, *gules*. Indeed, the terms closet and barulet are scarcely ever employed, but the word *bar* uniformly used instead.

Barry. When the field is divided by horizontal lines into four, six, eight, ten, or twelve equal parts, the intermediate spaces being filled with alternate tinctures, the bearing is called *barry*, and denominated, like paly, from the number of spaces. Barry should not be shaded, for a similar reason. Barry of eight, *argent* and *gules*, are the Arms of the Kingdom of Hungary. See fig. 18.

Party per fess. When a coat is divided by a horizontal line passing through the fess point, it is said to be *per fess*, or *party per fess*. This bearing was anciently termed *countertreviled*. Fig. 19, per fess, *sable* and *argent*, represents the Arms of the Canton of Friburg in Swisserland.

Fesswise. When a charge, having length, covers the fess point in an horizontal position, it is said to lie *in fess*, *fesswise*, or *fessways*, as in fig. 20, the Arms of the University of Oxford, *azure*, a book expanded *fesswise*, *argent*, having seven labels on the dexter side, bearing seals *or*, and inscribed *Dominus illuminatio mea*, between three crowns of the third. The same expressions are applied to any number of charges lying in the same direction.

Barwise. When several charges having length are ranged one above another horizontally, they are said to be placed *barwise*.

Chief. When the fess is removed to the upper part of the escutcheon, it is called a *chief*, for a reason already assigned. This ordinary, in latter times especially, is one of honourable augmentation. Fig. 21, the Arms of the Friars of St. Augustine, is *argent*, on a chief *sable*, a heart inflamed at the top, *proper*. The chief is sometimes surmounted by another, which, of course, is smaller.

Fillet. The chief has one diminutive, the fillet; its size is one-fourth of the chief, of which it occupies the lowest part. Fig. 22, the Arms of Cape, *sable*, a chief *or*, in the nether part thereof a fillet *argent*.

Party per chief. When a straight line coincident with the direction of the base of a chief divides the escutcheon, it is said to be party per chief. Party per chief, *gules* and *or*, are the Arms of Camoyse. See fig. 23.

In chief. Charges in the situation of the chief are said to be in chief. Thus, in fig. 20, the uppermost crowns are said to be *in chief*, and the other *in base*.

Combinations of the pale and fess. There is sometimes found a bearing, of which we have given an instance in fig. 24, the Arms of the Girdlers of London, and which is ordinarily blazoned thus: party per fess, *azure* and *or*, on a pale counterchanged, between two gridirons of the second in chief, the handles erect, another in like manner. But as the supposed pale is *never shaded*, and as no reason can be assigned for this, it seems more correct to blazon the coat, paly of three, *azure* and *or*, per fess counterchanged, three gridirons of the second.

Quarterly. When the shield is party per pale and fess both, it is said to be divided *quarterly*; and each of the divisions **Quarter.** is called a *quarter*. Fig. 4 and 5 are divided quarterly. The first of these would be blazoned, quarterly, first, *ermine*, second, *ermines*, third, *erminois*, fourth, *pean*. When the coat is simply parted into two colours, per pale and fess, it is usual to blazon, quarterly, naming the two tinctures, that in the dexter chief first, as in the Arms of Stanhope, quarterly, *ermine* and *gules*. A *quarter* is sometimes borne by itself on the dexter chief, as in the Arms of Stanton, vair, *argent* and *sable*, a quarter *gules*. (Fig. 25.) It is held to be a very honourable bearing. It is generally charged with a portion of National Arms, granted in consequence of some service: and some Heralds have held that it should not be granted to a person of lower dignity than a Baron. When the bearings of several families are marshalled in the same escutcheon, in compartments formed by horizontal and vertical lines, they are said to be *quartered*, and the **Quarterings** compartments are termed *quarterings*. The laws of these quarterings will be noticed when we come to treat of marshalling.*

Canton. The quarter has a diminutive called the *canton*. This term in French signifies a corner. The proportion of the canton to the field is not determined, only it must not occupy one-fourth. This, like the quarter, is a very honourable bearing, and is supposed to represent the banner given by the Sovereign to the Knight banneret. The Arms of Shirley, fig. 26, are paly of six, *or* and *azure*, a canton *ermine*. Sometimes the canton is borne in the sinister chief, and then it must be specified, a canton sinister.

Checky. When the divisions produced by several vertical and horizontal lines are filled alternately with heterogeneous tinctures, the result is termed checky, from *échec*, Fr. Fig. 27. Checky, *argent* and *gules*, is the Arms of Croatia, ensigned with the crown of the Kingdom of Hungary. But two rows of this by themselves are termed *countercompony*, and one row *compony*. When one whole shield is checky of nine, it is called by some Heraldic writers *a cross perforated*; but this is a very incorrect expression, since the cross is an ordinary, whereas the whole of this bearing is in the plane of the escutcheon. This bearing, *or* and *azure*, forms the Arms of the Republic of Geneva.

Cros. When the straight lines drawn palewise and fesswise enclose the fifth of the shield, (or the third if charged,) they form an ordinary which is called a *cross*. When this cross is *gules*, it is called the cross of St. George. *Argent*, a St. George's cross, was impaled by Charles I. with the Arms of England, and was employed afterwards as the Arms of the Commonwealth. The same is now the bearing of the Republic of Genoa, which is surmounted with the crown of Corsica. See it in fig. 28.

Voiding. The cross and some other ordinaries are subject to what is termed *voiding*; the inner part being taken out, and nothing left but a narrow border. When the extremities of an ordinary *not bounded by the escutcheon*, are also removed, the ordinary is said to be *voided throughout*. Heralds very justly condemn the expression "voided of the field," as it cannot really be voided of any thing else; and if the colour be different, they consider such the colour of the ordinary, and the other the border, and call it *fimbriated*. Yet the expression *voidie du champ* occurs in the Roll of Karlaverock.

Piercing. Crosses are sometimes *pierced*. That is, a portion of the ordinary is abstracted from the middle. There are three kinds of piercing: *round*, or *simple* piercing, when the part removed is circular; *lozengeways*, when it is in the form of a lozenge; and *quadrate* piercing, when it is square.

Plain. A cross *plain*, or *couped*, is where the ends of the ordinary do not quite reach the circumference of the escutcheon. *Gules*, a plain cross, *argent*, was the coat-armour of the Order of Knights Templars. See fig. 29.

Aiguisy. This cross is sometimes sharpened at each end to a point, when it is termed *aiguiscy*, (*aigu*, Fr.) or urdy. *Argent*, a cross aiguiscy, voided, *sable*, is the Arms of Dukenfield, Bart. See fig. 30.

Clechy. Sometimes the boundary line is curved, whence it is called *clechy*; some call this mascly. See fig. 39, which we shall presently explain.

Calvary. A cross *Calvary* is a plain cross, the bar somewhat elevated, and the whole raised on three *grieces*, *i. e.* steps. In such a manner are the crucifixes set at the entrance of towns in Countries professing the Romish Religion; from which circumstance this cross undoubtedly derives its name. It is sometimes found without steps, when it is termed a *long* or *passion cross*. It is exemplified in fig. 31, the Arms of the old Bishopric of Dunkeld, *argent*, a cross Calvary, *sable*, between two passion nails, *gules*.

Patriarch The *patriarchal cross* is *plain*, but has two bars, the upper smaller than the lower. It is the *insigne* of Patriarchs or Archbishops. It is not used by English Archbishops, but it generally forms part of the exterior decorations of the armorial bearings of Cardinals. The Arms of the Province of Lithuania are *gules*, a cavalier armed cap-a-pié, *argent*, mounted on a barded courser of the second, holding in his right hand a sword erect of the same, garnished *or*, and bearing on his left arm a shield *azure*, ensigned with a *patriarchal cross* of the second. Fig. 32.

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* "If you are to draw a coat which is blazoned or charged with three similar figures two and one, besides the quarter; as for example, argent, three torteauxes, a quarter azure; yet, although in the blazon you mention three, you must show but two in the drawing, the third being supposed to be under the quarter." Edmondson.

Lorrain. A cross *Lorrain* has the lower bar nearer the base, as in fig. 33, *argent*, a cross Lorrain, *gules*, the Arms of Hersfeld, quartered by the Prince of Hesse Cassel.

rosslet. A *crosslet*, or *cross crosslet*, is a cross *crossed* towards each end. See fig. 34, the Arms of Taddington, *or*, a cross crosslet, *gules*. Such a cross between four plain crosses is called a Jerusalem cross. *Argent*, a Jerusalem cross, *or*, was the Arms of the Christian Kingdom of Jerusalem. This is what would be called false Heraldry, although this bearing was sanctioned by ancient prescription. Some make the centre cross *potent*.

otent. A cross *potent* is one which terminates in crutch heads. The derivation of this word has been already explained. An example will occur presently.

rampony. A cross *crampony* is where the ends resemble cramp-irons. Azure, a cross crampony, *or*, are the Arms of Bulwark. See fig. 35.

ambeau. A cross *lambeau* is exemplified in fig. 36, *gules*, a cross lambeau, *argent*, for Rudetzker.

ouble-arted. A cross *double parted* is exemplified in fig. 37, *azure*, a cross double parted, *argent*, name, Doubler.

otency. A cross *potency* is a figure more easily drawn than described. See fig. 38. *Argent*, a cross potency, *gules*.

ommy. The cross *pommy* terminates in circles; from the resemblance of which to apples (*pommes*) it derives its name. Fig. 39, *azure*, a cross pommy, *argent*, is the ancient coat-armour of the Kings of Navarre, which Inigo Ximenes professed to have adopted at the suggestion of an Angel, who commanded him to make war on the Moors with a banner of this bearing. An ordinary, adorned with circles of this kind, is also called *pommetty*. Thus, fig. 40, the bearing of the Count of Thoulouse, is *gules*, a cross clechy pometty, voided, *or*.

otonny. A cross *botonny* is so called from the resemblance of its ends to buds, (quasi *boutonnée*, Fr.) It is exemplified in the Arms of Winwood, fig. 41, *argent*, a cross botonny, *sable*.

line. The cross *moline* terminates in representations of the ends of the *fer-de-moulin*, or milrind. *Argent*, a cross moline, *sable*, fig. 42, is the Arms of Dr. Alnwick, founder of the Philosophy School, Oxford.

ercly. When the extremities curve very considerably, it is termed *recercly*, or *anchored*. See fig. 43, *gules*, three crosses recercly voided, *argent*, a chief *vairy*, *ermine* and *ermines*, the Arms of Verney.

ry, or oncy. The cross *flory* differs from the moline in having three points at each end, instead of two. The term flory is sometimes applied to a very different cross, being *plain*, with a *fleur-de-lys* at each end. It may be better to call the present cross *patoncy* (*à patendo*) than *flory*, because, whatever name we may assign to this bearing, such a cross as that last mentioned would necessarily be called flory, as we shall, in our progress, have occasion to observe. But it should rather be blazoned, couped and flory at each end. Some make the extremities of the patoncy cross more erect, and distinguish between it and the flory cross. We give an example of this latter in fig. 44, the Arms of Bolton Priory, Yorkshire, *gules*, a cross patoncy, *vair*.

or y. The cross *paty*, like the former, has its name from the breadth of its arms. It is exemplified in fig. 45, the Arms of the See of Lichfield and Coventry. Per pale, *gules* and *argent*, a cross potent, quadrated in the centre,* counterchanged, between four *crosses paty*, the two in the dexter pale *or*, those in the sinister of the first. This cross is sometimes called *formy*.

Firmy. A cross of this kind reaching to the circumference of the shield is called a cross *firmy*. *Argent*, a cross paty firmy, *sable*, is the Arms of the city of Constance. See fig. 46.

Crosslet Paty. A cross terminating every way like a cross paty is called a crosslet paty. Argent, a crosslet paty, *sable*, is the bearing of Crossfall. See fig. 47.

There are also crosses paty concave and paty convex. *Argent*, a cross paty convex, *gules*, is the bearing of Wandley; and *gules*, a cross paty concave, *or*, is that of Honstein. See figs. 48 and 49. The paty and other crosses are sometimes *rebated*, *i. e.* lose their angular parts.

Maltese. The cross of Malta, little differing from the cross *paty*, except that the ends have double points, is rarely to be found in English arms. It is part of the insignia of the Knights of Malta, whence it derives its name. It is found in no English military Order, except that of the Bath, the jewel of which, in this form, is given in fig. 50.

Avellane. The cross *avellane* is derived from *avellana*, the hazel-nut, which it somewhat resembles.

Paternoster. The *paternoster* is a cross formed of beads.

Fitchy. A cross is said to be *fitchy* when the lower limb is sharply pointed, as if to stick (*fixer*) in the ground. (We shall give an example under the *bend*.) Fitched. And it is said to be *fitched in the foot*, when a point is added at the bottom of the lower limb. Crosses borne as standards in the Crusades, and on other solemn occasions, were sometimes pointed at the end for the purpose of pitching when the army encamped. The traditional Arms of Edmund Ironside, King of England, fig. 51, are *or*, a cross paty, fitched in the foot, *azure*.

Degraded. A cross is said to be *degraded* when the ordinary is bounded by steps (*degrés*) towards the circumference of the escutcheon, as in fig. 52, the Arms of Wyntworth, *argent*, a crosslet degraded, *sable*.

Crusilly. When the field is covered with numerous little equi-distant crosses, it is said to be *crusilly*.

Crosswise. When several charges are disposed in the form of a cross, or when two charges having length are placed vertically and horizontally, they are said to be placed *crosswise*.*

Bend. The *bend* is an ordinary bounded by parallel lines, equally distant from the line joining the dexter chief and sinister base. It contains the fifth part of the escutcheon uncharged, and the third charged. Its name may be derived from its *bended* position; but, more probably, from the French *bande*, since all its diminutives, except the *cost*, have names derived from the same idea. Fig. 52* is the Arms of the noble family of Howard, Duke of Norfolk, hereditary Earl Marshal of England, *gules*, a bend, *argent*, charged with an escutcheon of Scotland in the dexter chief, between six crosslets fitchy of the second.

Bendlet. We scarcely know whether the *bendlet* should be con-

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* When the centre is formed like a circle the cross is said to be *nowed*; when like a square, *quadrated*.

* The reader, in the course of his Heraldic studies, will discover that we have here set down only the principal crosses. To attempt the description of all would be impossible in this Essay, and we question whether this has ever been done. Juliana Berners, at least, authoress of the *Book of St. Albans*, gave up the idea in despair. "Now," says she, "I turne ageyne to the signe of the cros, and ask a question. How many crosses be borne in armys? to the wich question, under a certein nowmbur, I dare not answere, for crossis INNUMERABULL are borne now daily."

sidered a diminutive of the bend. Gwillim is of the negative opinion, despite its name and general resemblance. The reason why Heralds have hesitated on this point is, that the bendlet, although occupying *nearly* the relative position of the bend, does never *exactly* occupy it; the upper side being in the exact corner of the escutcheon, and passing through the fess point. The bendlet, according to Gwillim, whose authority we follow on the litigated point of the content of the diminutives of the bend, should never occupy above one-sixth of the field. Fig. 53 is the Arms of Lord Byron, *argent*, three bendlets enhansed,* *gules*.

Garter. An ordinary containing one-half the bend is called a *garter*.

Cotise. The fourth of the bend is called a *cotise*, or *cost*, from *costa*, a rib. This ordinary is generally found in company with the bend, one on each side; whence the name. "When one of these is borne alone, then shall you term it in blazon a *cost;* but if they be borne by couples in any coat, (which is never, saith Leigh, but when a bend is placed between two of them,) then you may name them *cotises*."† Also a bend thus situated is said to be cotised. See fig. 54, the Arms of Fortescue, *azure*, a bend ingrailed, *argent*, cotised, *or*.

Riband. The *riband* contains the eighth of the bend; and it may be remarked concerning its name, that it unites the derivations of the bend and the cotise. Fig. 55 is blazoned *argent*, a bend traverse, *sable*. Name, Travers.

Bendy. When the whole field consists of alternate spaces of heterogeneous tincture, bounded by equidistant lines in the direction of the bend, it is called *bendy*. See fig. 56, bendy of ten, *sable* and *argent*, the bearing of the Duchy of Angoulême.

Party per bend. When the escutcheon is bisected by a line in the direction of the bend, it is called *per bend*, or *party per bend*. Anciently, this bearing was called *lentally*. Fig. 57, party per bend, embattled, *argent* and *gules*, is the bearing of the famous Philosopher Boyle, and of the Earls of Shannon, and Cork and Ossory, in Ireland.

Bendwise. When a charge having length lies in the direction of the bend, or when more charges than one are arranged in this direction, the charge or charges are said to be *bendwise*, or *bendways*, or *in bend*. An example will occur, fig. 66.

Combination of the pale and bend. Paly-bendy. When the field is divided into spaces filled alternately with heterogeneous tinctures, by lines in the direction of the pale and bend, it is said to be *paly bendy*. Paly bendy, *argent* and *azure*, are the Arms of Bavaria. See fig. 58.

Combinations of the fess and bend. Barry bendy. When lines drawn bendwise and barwise enclose alternate spaces of metal and colour, the bearing is termed *barry bendy*. *Gules*, a fess barry bendy, *argent* and *azure*, is borne by Husberg. See fig. 59.

Gyron. If a line drawn from the dexter chief to the fess point meet another drawn through that point fesswise to the dexter side of the escutcheon, the enclosed space forms the ordinary which is called the *gyron*. We derive its formation in this manner, because when a *gyron* is borne by itself, it is always made thus, unless otherwise specified. But every ordinary enclosed by the circumference of the escutcheon and by two lines meeting in the fess point, is called a gyron. *Argent*, a gyron, *gules*, is the bearing of Gyronell. Fig. 60.

Gyronny. Hence is derived the term *gyronny*, which is applied where the whole field is divided by lines crossing each other in the fess point, and the spaces filled with alternate tinctures, not homogeneous. It is denominated from the number of spaces or *pieces*. Gyronny of six and gyronny of eight are those in greatest requisition; the word seems to be derived *à gyrando*, which appears more clearly from the gyronny than the gyron. Gyronny is by early armourists called *contrary coned*. Gyronny of six, *azure* and *or*, are the Arms of Ambery; of eight, *or* and *sable*, those of Campbell. See fig. 61, 62.

Bend sinister. The *bend sinister*, although only differing from the common bend in its position, which is from sinister chief to dexter base, is considered by armourists as a separate ordinary, on account of the difference in its subdivisions. *Gules*, a bend sinister, *argent*, is the bearing of Barber. Fig. 63.

Scarp. The *scarp* is a diminutive containing one-half of the bend (*écharpe*, a scarf, Fr. which it considerably resembles.)

Baston. The *baston*, or *batune*, as it is sometimes corruptly called, (*baston*, Norm. Fr., a truncheon,) contains one-fourth of the bend sinister, but never reaches quite to the circumference of the escutcheon. Of the use of this ordinary we shall speak in treating of marshalling. Meantime an example of it will be found in fig. 64, the Arms of the noble family of Fitzroy, Duke of Grafton. Quarterly first and fourth, quarterly again, first and fourth France, second and third England, second Scotland, third Ireland; over all a *baston* company of six, *gules* and *argent*. The baston is the *insigne* of a marshal; two are placed behind the shield, *sable*, tipped *or*, and they lie in opposite directions; the sinister direction being no longer essential. This may be seen in fig. 52* the Arms of the Earl Marshal.

Party per bend sinister. When the escutcheon is bisected by a line in the direction of the bend sinister, the coat is blazoned *per bend sinister*, or party per bend sinister. See an example in fig. 65, the Arms of the Canton of Zurich, per bend sinister, *argent* and *azure*.

In bend sinister. The expression *in bend sinister* is applied when any charge having length is disposed in this manner; or when any number of charges are so arranged. Fig. 66, the Arms of the Episcopal See of Winchester, are *gules*, two keys endorsed in bend, the uppermost *argent*, the other *or*, and a sword in bend sinister, interposed between them, of the second, hilted of the third.

Combination of the bends. Saltire. The two bends in combination form an ordinary, which is called a *saltire*, *à saliendo*, because it seems to *leap* across the escutcheon. The Arms of the See of Bath and Wells (fig. 67) are *azure*, *à saltire* quarterly quartered,* *or* and *argent*. When a saltire is cut off by horizontal lines at chief and base, it is called *humetty*.

Saltire humetty.

Saltirewise. Charges having length, placed in the direction of the saltire, are said to lie *in saltire*, *saltirewise*, or *saltireways*. Thus the Arms of the See of London (fig. 68) are blazoned *gules*, two swords *saltirewise*, *argent*, hilted *or*. The same expression applies to any number of charges arranged in this direction.

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* An ordinary is said to be *enhansed* when it is placed above its proper position in the escutcheon. In the example the *lower* side of the lowest bendlet passes through the fess point instead of the higher. It is, however, called a bendlet, because the side passes *exactly* through this point. And the other ordinaries being the same in capacity, receive the same name. We may add that the diminutives of the bend are much controverted.

† Gwill. ch. iv. sec. 2.

* This expression applies to saltires and crosses when they are bisected by straight lines crossing each other, and the alternate spaces are filled with different tinctures.

A crosslet in saltire is called a St. Julian's cross. *Argent*, a St. Julian's cross, *sable*, are the Arms of Julian. When the coat is divided by two lines in the direction of the saltire, and the alternate spaces are filled with tinctures not homogeneous, it is blazoned *per saltire*, or *party per saltire*. The same is sometimes called *gyronny of four*.

Party per saltire.

Lozengy. When the field or charge is divided by many lines drawn saltirewise into spaces filled with alternate tinctures not homogeneous, it is called lozengy, (lozengy, *argent* and *gules*, fig. 69, is the Arms of the Prince of Monaco,) and each of the compartments is termed a lozenge, (*lauringia*, from its shape,) which is often borne as a separate ordinary, and is always the form of the escutcheon which contains the bearings of unmarried females. The lozenge is not limited to any particular capacity. Edmondson makes the width of the lozenge three-quarters of its height; but on this authors differ. When a lozenge reaches every way to the circumference of the escutcheon, it is called *a grand lozenge*, or a lozenge throughout. See fig. 70, the Arms of the Count of Graffen Egg; *gules*, a grand lozenge *argent*.

ozenge.

Mascle. A lozenge voided is called a *mascle*, (*macula*, the mesh of a net, which this ordinary exactly resembles.) But Edmondson says, "according to the sentiments of *all* authors, it should be an exact square." Who these authors are it is not so easy to specify. See fig. 71, the Arms of the city of Rouen, *gules*, nine mascles, three, three, and three, *or*. Lozengy voided is called *mascally*.

ret. A *fret* is a mascle interlaced with a saltire. The term seems to be derived from *fretus*, the ordinary representing sticks *supported* by each other. See fig. 72, *argent*, a fret, *sable*, the Arms of Vernon. Sometimes we find a fret of *eight pieces*.

etty. When the field or charge is covered with bendlets dexter and sinister interlaced at equal distances, after the manner of the fret, *but exceeding eight pieces*, the bearing is called *fretty*. Fig. 73, *argent*, fretty, *azure*, is the bearing of De Montier Aullier. It is astonishing that etymologists should here have thought of the *fretting* of water over the stones of a brook. The derivation is obviously from the *fret*, and its etymology ultimately the same. When charges appear between the frets, the bearing is called *diaper*.

tted. Charges alternately crossing each other are said to be fretted. Azure, three trouts *fretted in triangle*, testeà-la-queue, *argent*, are the Arms of Troutbeck, quartered by the Talbots of Grafton. See them, fig. 74.

il. The lozenge somewhat elongated takes the name of a *fusil*, from *fusce*, the old Norman word for a spindle, which its form resembles. *Azure*, five fusils in fess, *or*, are the Arms of the Abbey of Salley. Fig. 75.

lly. When a shield or charge is divided into fusils of two tinctures alternately, it is called *fusilly*, and further denominated from the *direction* of the fusils. If they lie palewise, it is called *fusilly* only; if barwise, *fusilly barry*; if bendwise, *fusilly bendy*. Fusilly and *ermine* on a chief of the first, three lilies *argent*, is the Arms of Magdalen College, Oxford. Fig. 76.

re. The lozenge pierced is called a *rustre*. See fig. 77, *azure*, three rustres, *argent*, the Arms of Lebaret.

ron. The *chevron* may be considered as the progeny of the saltire, as consisting of the lower half of that ordinary brought to a point on the upper side. Some assign to this ordinary one-fifth, and some one-third, of the escutcheon. The latter may always be assumed when the ordinary is charged. Chevron, in French, signifies the support of a slanting roof formed by one rafter lying against the other, which is precisely the shape of the ordinary. The chevron is always shaded on the two lower sides, not on one lower and one upper. Many examples of this ordinary will occur as we proceed.

Concerning the locality of this ordinary, great is the contest among armorists. The grave and decorous Gwillim* is excited to almost unbecoming warmth by those "common disorderers of these tokens of honour," "the common painters," who have ventured to depress the vertex of the chevron from the middle chief to the honour point. But notwithstanding this venerable authority, the practice of Heralds has been to follow this corrupt example. Yet is the chevron found in various situations. Sometimes a fess occurs between two of them. Sometimes it stands on one side of the escutcheon, in which case it is called *tourny*, and denominated from the side. *Or*, a chevron tourny, sinister, *gules*, is the bearing of Tournay, see fig. 78: the same bearing is sometimes called a chevron *couched*, *counter-turned*, or *counter-pointed*. Sometimes we find them *interlaced*, or *braced*, as in the Arms of Fitzhugh, fig. 79, *azure*, three chevrons interlaced, a chief, *or*. The chevron is beside subject to couping and voiding, and to an operation called *removing*, which will be better understood by a representation than a definition. See fig. 80, a chevron removed, a chief, *argent*, the Arms of Wolfsthall. Another form of this ordinary is called *debrused*, or *fracted*. See fig. 81, *azure*, a chevron debrused, *argent*, name, Winterfall. Fig. 82 presents a form which is also called a chevron removed. Perhaps it would be more correct to call it *removed one joint*. When the middle part of the chevron is wholly taken away, it is said to be *disjointed*. See fig. 83, *gules*, a chevron disjointed, *or*, name, Discord.

Chevron removed.

Chevronel. An ordinary containing one-half the chevron, but having the same shape, is called a *chevronel*. The Arms of Clare (fig. 84) are *or*, three chevronels, *gules*.

Couple close. An ordinary containing one-quarter of the chevron is called a *couple close*, which always is found in company with the chevron, one on each side, which in that case is said to be *cotised*. Edmondson, however, calls all diminutives of the chevron chevronels, and only applies the term couple-close when the ordinaries are placed in pairs; but in this he is not generally followed.

Party per chevron. When the escutcheon is parted by two lines in the direction of the chevron, meeting in or a little above the fess point, the coat is said to be *per chevron*, or *party per chevron*. Party per chevron, *sable* and *argent*, are the Arms of Aston. See fig. 85.

Chevronny. When the field or charge is divided into parallel spaces in the form of chevrons, occupied with alternate metal, &c. not homogeneous, such bearing is called *chevronny*, and is further denominated from the number of its pieces, as paly, barry, &c. Chevronny of eight, *argent* and *vert*, is the bearing of Chevronney. Fig. 86.

Chevron wise. When charges assume the form of the chevron, they are said to be placed *in chevron*, *chevronwise*, or *chevronways*. Argent, a heart, *gules*, pierced by two swords chevronwise, *azure*, is the bearing of Pearson. Fig. 87.

When the bends and pale terminate where they meet, they form the ordinary called the *pall*, from its resem-

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* Ch. vi. sec. 2.

Combination of the bends and the pale. Pall, or pairle.

blance to the *pallium* of patriarchs and archbishops. Some call it the *pairle*, from the French, after the Latin *pergula*. And it may be well to distinguish it from the *actual* pall, which, as we shall have occasion to observe, sometimes occurs in coat-armour. Fig. 88, *or*, a pairle, *gules*, is the Arms of Pauling.

Pile.

We may here conveniently notice the ordinary called the *pile*, which is commonly enclosed by two lines drawn from the upper side of the escutcheon meeting in a point; and this we ought to do in this place according to the opinion of those who consider it the natural offspring of the saltire, as being the space enclosed in chief by the boundary lines of that ordinary. To this opinion, however, we do not subscribe; as the pile always reaches below the fess point, while the point of intersection of the upper lines of the saltire falls always above it. Beside which circumstance the position itself of the pile varies in a manner to destroy all analogy between it and the saltire, or rather the space in chief of the saltire. We prefer, therefore, to consider it an independent ordinary. It seems singular that its etymology should ever have been questioned. It is so exactly a representation of a *pile* on which bridges, &c. are built, that nothing can be more so. Fig. 89, the Arms of Chandos, are *argent*, a pile, *gules*.

"When there is but one pile in the field it must contain the third part (of the escutcheon) at the chief."* Such is Gwillim's rule. But practice does not universally confirm it. When several piles are borne in one coat, they must converge towards the base, unless otherwise specified. See fig. 90, *argent*, three piles, *gules*, for Gildsbrough. Fig. 91 is blazoned, *argent*, a triple pile in base per bend sinister, *vert*, flory, *sable*.

Pily.

When the shield is parted by zig-zag lines into more than three spaces, the bearing is said to be *pily*. This is a very uncommon bearing. It is called *barry pily*, or *bendy pily*, when in direction of the bar or bend; but when in direction of the pale, *pily* only. But when there are only three spaces or pieces, it is called *party per pile*; and the words *traverse*, *inverse*, *per bend*, &c. are added, according to the position of the lines. Per pile traverse, *argent* and *gules*, are the Arms of Rathlow. Fig. 92. Per pile inverse, *or*, *gules*, and *sable*, those of Meinstorff. Fig. 93.

Party per pile.

Pilewise.

When several small charges are arranged in the form of an inverted pyramid, or when charges having length meet in the base and widen at the chief, they are said to be borne *in pile*, *pileways*, or *pilewise*. When three charges alone are borne, and no specification is made, they are always understood to be borne pilewise.

Bordure.

We have now discharged the consideration of the great ordinaries, and those which are either their diminutives or derivatives. The next object which appears to claim our attention is the *bordure* or *border*, whose name sufficiently conveys its description. It occupies one-fifth of the escutcheon. Edmondson and some other writers of authority do not allow the bordure to be shaded, which would deprive it of the nature of an ordinary altogether, which is a charge, and reduce it to a mere division of the shield. But as it is generally regarded as an ordinary, it ought, on that account, to be shaded. The bordure, if of fur, formerly was blazoned "*perflew* of ermine, ermines, &c." or whatever the fur might happen to be; if charged with beasts, it was blazoned "*enurny* (*en orné*, Fr.) of lions, &c;" if with birds, "*enaluron*, (*en orle*, Fr. *in a border*,) of eagles, &c.;" if of plants, *verdoy*, of roses, &c.; and if of other inanimate objects, "*entoyry* (*entouré*, surrounded) of crosslets," &c. But these useless distinctions have now given way to the usual mode of blasonry. When the bordure is simply *adumbrated*, the arms must be blazoned as in fig. 94, the Arms of Magdeburg; per fess, *vert* and *argent*, each *imbordured*.

Blazonry.

Tressure.

A border running parallel with the sides of the escutcheon, containing about one-quarter of the bordure, is called a *tressure*. It is generally double, and sometimes triple, and it is most usually *flory-counterflory*, *i. e.* ornamented with *fleurs-de-lys*† alternately arranged in opposite directions. This bearing makes a part of the Arms of Scotland, and, as it is pretended, was a present of honour from Charlemagne to Achaius, then King of that Country. Several Scottish coats have the tressure, particularly that of the Royal House of Stuart, which occurs in fig. 95: *or*, a fess checky, *argent* and *azure*, within a double *tressure*, flory-counterflory, *gules*.

We do not here mention the *orle*, which some consider a diminutive of the bordure, because we rather regard it as referable to the inescutcheon, which we shall presently notice.

Flanch.

A subordinate, but strictly independent, ordinary is the *flanch*, which is contained by the circumference of a semicircle and the side of the escutcheon. Two of these are always borne together. They have diminutives contained by ellipses of different eccentricity and respectively called *flasques* and *voiders*; but concerning these armorists are not agreed, some making the *flasque* the principal ordinary, and the flanch the derivative. The distinction, however, is now obsolete, and all figures of this kind are known by the common term of *flanch*. *Or*, two flanches, *gules*, were the Arms of Lancroft Priory, Cumberland. Fig. 96.

Flasques and voiders.

Inescutcheon.

An escutcheon placed upon the fess point is called an *inescutcheon*.‡ "This ordinary containeth the fifth part of the field," saith Leigh, "but his demonstration denoteth the third part." So observes Gwillim; and perhaps the best way of reconciling this contradiction will be to allow this ordinary, like some others, the third part when charged, and the fifth part otherwise. It is evident that this ordinary must not encroach too much on the escutcheon, as then the remainder would become a bordure. Some Heralds call all escutcheons borne as arms inescutcheons; but the ancient practice was certainly to restrict this term to an escutcheon borne on the fess point.

Orle.

An inescutcheon voided is called an *orle*, (*orula*, Latin, little border,) which contains the half of a bordure. An orle is sometimes borne double, or triple, that is, one or more orles within another. *Gules*, an orle, *argent*, is the Arms of the family of Baliol; hence of Baliol College, Oxford. Fig. 97.

Charges disposed in the form of an orle, are said to be *in orle*.

These are the bearings usually comprehended under the name of ordinaries. To these may be added the file, lambeau, or *label*, (by which last name it is most

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* Gwil. ch. vi. sec. 2.

† The *fleur-de-lys* is a bearing so well known, as scarcely to need description. Yet we should not have deviated from our orderly arrangement by introducing it in this place, except from necessity. The tressure has every right to be considered a variety of the bordure; and the *fleur-de-lys* is its usual companion.

‡ Of whatever form the escutcheon is, the inescutcheon *generally* follows it.

commonly blazoned,) a figure consisting of one piece reaching across the shield, and several at right lines to it, which are called points. This figure is by some writers excluded from the honours of an ordinary, and considered only as a family distinction. But Gwillim has produced several coats in which it is undoubtedly a bearing; as for example, fig. 98, that of Liskirk, *or*, three labels, barwise, *gules*, the first of five points, the second of four, and the third of three. The abatements we reserve to the division on marshalling. We shall now advance to the discussion of those bearings which are called common charges, first briefly noticing those known by the name of *Roundels* and *Guttes*.

oundels, th their stinctive pella- ns.

A *roundel* is a circle, supposed to be emblematic of a blow sustained in the shield. Foreign Heralds call all roundels indiscriminately *tourteaux*, but this name in English Heraldry is restricted to the red roundel. The roundels are denominated as follows:

Gold. *Bezant*, from Byzantinus, (*sc. nummus*,) the gold coin of Byzantium.

White. *Plate*, from the Spanish *plata*, silver.

Red. *Tourteau*, Fr. a kind of cake.*

Blue. *Hurt*, a flower of a blue colour.

Green. *Pomme*, Fr. an apple.

Black. *Pellet*, *Ogress*, or *Gunstone*. The first of these terms is most in use.

Purple. *Golpe*, which some (*si Diis placet*) derive from the verb to *gulp*.

The orange-coloured roundel naturally takes the name of that fruit; and the "sanguine" is termed *guze*, from *gueuse*, Fr. a mass of heated metal; it represents a heated cannon ball. The last two are very rarely used.

The above names are always employed by English Heralds, who never blazon "a roundel *or*," &c. but always, "a bezant," &c.; except only in counterchanges, where this mode of blazon would be awkward and prolix. Thus the Arms of Abtot, Earl of Worcester in William Rufus's time, fig. 99, are, according to Gwillim, "per pale, *or* and *gules*, three roundels counterchanged." And where the roundel is of fur, or of equal tinctures; as, a roundel ermine, a roundel checky, &c. Some represent the bezant and plate flat, and the other roundels spherical. But as the lower roundel in this coat must partake of gold and red, in order that the three may be arranged pilewise, (see under *pilewise*,) it is obvious that this rule must be violated here.

A roundel barry wavy of six, *argent* and *azure*, is called *a fountain*, of which natural object it is a rude representation. This roundel is always represented flat. When the field or charge is strewed with equidistant roundels, it is said to be *bezanty*, *platy*, *pommetty*, *hurty*, *pelletty*, *semy of torteaux*, *semy of golpes*, *semy of oranges*, *semy of guzes*, according to the nature of the roundel.

s.

Guttes are devices resembling drops, from *goutte*, Fr. a drop. They are most generally borne at equal distances, scattered over the whole shield or charge, which thence is said to be gutty, with the following distinctions.

Blazonry.

If the drops be of gold, the object is denominated *gutty d'or*.
white.................................*d'eau*.
red....................................*de sang*.
blue...................................*de larmes*.
black..................................*de poix*.
green..................................*d'huile d'olive*.

An illustrative example will be found in fig. 100, the Arms of the Penitents of St. Francis, *sable*, gutty d'eau, in chief a dove with wings expansed descending, *argent*.

COMMON CHARGES.

Next to the ordinaries come to be considered the common charges, under which name is comprehended every other species of charge. We shall class them into animate and inanimate.

Animate.

1. Animate charges are 1. celestial; 2. terrestrial; 3. chimerical. All animate charges are represented moving towards the dexter side of the escutcheon, unless otherwise specified; if they respect the sinister side, they are said to be *contourny*.

Celestial.

1. Celestial animate charges are angels and cherubim. The vulgar representation of an angel, an human figure with wings, is too well known to make any particularizing necessary.

A cherub is an infant face between two or more wings. Fig. 101, *sable*, a chevron between three cherubim, *or*, is the bearing of Challoner.

Terrestrial.

2. There are some terms which indifferently apply to all kinds of terrestrial creatures; such as *couped*, where the charge is abruptly terminated in a straight line; an expression which we have already seen applied to ordinaries; *erased*, where the charge terminates in three parts; *demy*, where the *couped* upper half of the creature is represented; *gardant*, when the full face is exhibited; *regardant*, when turned back over the shoulders.

Man.

The human figure, as might be expected, enters largely into Heraldry; not, however, so *technically*, as to render it necessary to give many examples. Man is said to be *crined* of the colour of his hair.

The most remarkable human figure which is the strict property of Heraldry, is what is called a *Prester John*, *viz.* a Patriarch seated, bearing in his mouth a drawn sword fesswise, his dexter hand erect, the fourth and fifth finger bent; his sinister holding a book expansed.* *Azure*, a Prester John, *proper*, are the Arms of the See of Chichester. Fig. 102. The Prester John appears to be the Evangelist John, who calls himself, κατ' ἐξοχὴν, in his two last *Epistles*, ὁ πρεσβύτερος; and the sword is the representation of "the sword of the Spirit, which is the word of God."

A human arm bent back is said to be *embowed* when the elbow is to the dexter side; when to the sinister, *counter embowed*; a hand extended, with the palm presented, *apaumy*. If armed, the arm is called *vambraced*. (*avant-bras*.)

Fig. 103 presents a bearing somewhat fantastical, which is blazoned thus: *gules*, three legs armed, proper, conjoined in fess at the upper part of the thigh, flexed in triangle, garnished and spurred, *or*. This is the bearing of the Isle of Man.

Beasts.

Beasts are said to be *passant* when represented as *passing* or walking by; *rampant*, when rearing; *saliant*, when springing forward; *sejant*, when sitting; *statant*, when standing; *current*, when running; *couchant*,† when

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* It is said that a Spanish Prince, being about to engage the Moors, encouraged his men to eat a quantity of cakes, by telling them, that as many cakes as each man ate, so many Moors he would kill in the battle. After the victory, the various Chiefs, in memory of the occurrence, assumed in their bearings as many cakes as they had respectively eaten. This tradition is applied to explain the frequency of tourteaux in the arms of the Andalusian nobility.

* No Heraldic figure is more variously represented than the Prester John. Our representation is taken from an authoritative drawing in the College of Arms.

† Beasts of prey are said to be *couchant*; beasts of chase, *lodged*. The same distinction obtains respectively between the terms *saliant* and *springing*, *passant* and *tripping*. Lions feeding are *rapin*.

lying; *dormant*, when sleeping; *nascent*, when rising out of the *midst* of any ordinary, &c.; *issuant*, when from the top or bottom. The lion on the crown of Scotland, in a sejant gardant position, is said to be *assis*. (seated.) They are called *dismembered*, when their heads, tails, and feet are separated from their bodies. When rampant in opposite directions, front to front, they are termed *combatant;* when back to back, *addorsy*. When two animals are represented side to side, as in fig. 104, but moving in opposite directions, they are said to be *countertripping*, *counterpassant*, *countersaliant*, &c. as the case may happen. The example is blazoned, *sable*, two hinds, countertripping, *argent*. Beasts are also called *debruised*, when a charge is placed over them. They are said to be *armed* and *langued* of the colour of their claws and tongue;* *queued*, of their tails; *unguled*, of their hoofs; *armed*, of their horns, except deer, which are *attired*. When the head only is presented without any part of the neck, it is said to be *cabossed*. (*cabeça*, Span. *head*.) Fig. 105, the Arms of Mackenzie, are *azure*, a stag's head cabossed, *or*.

A deer statant gardant is said to be *at gaze*.

Lions are said to be *coward*, when the tail is brought down between the legs; *defamed*, when the tail is altogether taken away; *baillony*, when they bear a baston in the mouth. If more than one appear in a coat, they are called *lioncels;* but this distinction is now little observed. The whole foreleg of the lion is called a *gamb*. (*jambe*, leg, Fr.) If the lower joint only be represented, it is called a *paw*.

An extraordinary bearing is noticed by Gwillim, (chap. xv. sec. 3.) which we have copied, fig. 106. It is thus blazoned by him; "the field is Mars, (*gules*,) a *tricorporated* lion, issuing out of the three corners of the escutcheon, all meeting under one head in the fess point, sol, (*or*,) armed and langued, Jupiter (*az.*)" For whose Arms this blazon is intended, we are not informed. Edmund, Earl of Lancaster, brother of Edward I., and one of the ancestors of the Earl of Totness in Gwillim's time, is mentioned by him as bearing Arms not very dissimilar from these.

A *holy lamb* is a lamb passant, *proper*, his head surrounded with a glory, *or*, and supporting in his sinister ungule a staff, *argent*, ending in a cross, ensigned with a flag of the third, charged with a cross, *gules*. The Arms of the Middle Temple, London, are *argent*, on a cross of England, a holy lamb. Fig. 107.

Birds.

Birds are said to be *membered* of the colour of their bills and talons, except they be of prey, when they are said to be *armed*. And their bills and talons are called *members*. Their wings are *displayed*, when open; *erect*, when extending upwards; *inverted*, when downwards; *close*, when closed. When the wings are displayed, and the bird's body lies in fess or bend, it is said to be *volant* in fess or bend. So *argent*, a heron volant in fess, *azure*, between three escallops *sable*, is the bearing of Herondon. Fig. 108. The swan and other heavy birds, opening their wings to fly, are termed *rousant*. When they look behind them, they, as well as beasts, are called *regardant*.

Birds are sometimes *displayed*, which is a kind of bearing better explained by an example than by any definition. Our example shall be the Arms of the town of Bedford, fig. 109, *argent*, an eagle displayed, wings inverted, *azure*, ensigned with a triple tower of the first.

Sometimes Heraldry superadds to Nature, as in the escutcheon of Russia, fig. 110. *Or*, an eagle with two heads displayed, *sable*, each ducally crowned of the field, the whole imperially crowned, beaked and membered, *gules*. In the dexter foot a sceptre erect, in the sinister a mound proper, on the breast an escutcheon, *gules*, charged with a cavalier slaying a dragon, *argent*. A peacock with his tail displayed is said to be *in his pride*, and a pelican feeding her young is *in her piety*. The cock is said to be *crested* of the colour of his comb, and *jollopped* of that of his wattles. The *Cornish chough* is represented as a raven membered and beaked, *gules*.

If the word *bird* alone be used in blazon, the form must be that of a blackbird; but the colour as blazoned. If more *eagles* than one appear in the shield, they are properly called *eaglets*. But this minutia is often overlooked. Two wings conjoined, inverted, are said to be in *lure*. See the Arms of Seymour, fig. 111, *azure*, two wings conjoined in lure, *or*.

When three ostrich feathers are borne together, they are called a *plume;* if they exceed three, they must be blazoned *a plume of feathers*. Rows of feathers are called *heights;* or they may be blazoned *a double*, *triple*, *&c. plume*.

A swan's head should always be blazoned *a swan's neck;* a mode of expression never applied to any other bird.

The cassowary is Heraldically termed an *emew*.

Fishes.

Fishes, when in pale, are said to be *hauriant;* when in fess, *naiant*. When a whale or dolphin is borne, it is necessary to particularize whether it is *embowed* or *extended*. *Azure*, a dolphin *embowed*, hauriant, *or*, is a coat always borne quarterly with the Arms of France, by the Dauphin. It will be found in fig. 112. *Gules*, three bars, wavy, *or;* in chief, three escallops of the second, over all a dolphin, *azure*, are the Arms of the town of Poole. Fig. 113.

Other fishes are sometimes *embowed*, when two occur in the escutcheon. If they turn towards each other, they are said to be *respecting;* if in an opposite direction, *endorsed*. The Arms of Colston are, *argent*, an anchor in pale, inverted, the flukes in the mouths of two dolphins respecting, *sable*. Fig. 114. *Gules*, two pikes hauriant, endorsed, *or*, are the Arms of the dominion of Phiert. They are ensigned with the crown of Wurtemberg. Fig. 115.

Angues.

Serpents, and animals of the genus *anguis generally*, are said to be *nowed*, when they are repeatedly twisted in knots.

Chimerical figures.

3. Chimerical figures, or monsters, are usually preposterous combinations of real animals.

Those compounded with the human form are, the Sagittary, the Man-tiger, the Sphinx, the Harpy, the Triton, and the Mermaid.

The *Sagittary* is well known as the representation of the zodiacal sign of that name. It represents a Centaur, or creature of which the upper half is human, and the lower the body of a horse, holding an arrow on a bended bow. The instance which we shall select is rather curious, being the Arms of Stephen, King of England, adopted by him in consequence of his landing in England when the sun was in the sign Sagittarius. He changed the heads of the leopards into human bodies, the leopard supplying the place of the horse, thus making the Arms of England, *gules*, three leopard-sagittaries in pale, passant regardant, *or*. Fig. 116.

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* Lions are always armed and langued *gules*, except the field or charge be *gules;* in which case azure is substituted. And all beasts azure are armed *gules*, and *vice versâ*.

The *Man-tiger* is a chimerical animal, having the face of a man, the mane of a lion, the body of a tiger, and two straight horns. *Or*, a man-tiger, *gules*, armed of the field, is the bearing of Helter. See fig. 117.

The *Sphinx* is an emblematical object of Egyptian superstition, having the head and breasts of a woman, the body of a lion, and two broad plumed wings. If these are omitted, it is called a *sphinx sans wings*. It has been added to the Arms of officers who signalized themselves in the war with the French in Egypt. The crest of Asgill, fig. 118, is a Sphinx sans wings.

The *Harpy* is an animal having the upper part of a woman, and the lower parts and wings of a bird; *Virgineæ volucrum facies*, as the whole idea is happily conveyed by Virgil. Fig. 119 expresses the armorial bearings of the city of Nuremberg, *azure*, a *Harpy* displayed, crined, crowned, and armed, *or*.

The *Triton* is an animal uniting the upper part of a man with the lower of a fish. See fig. 120, the bearing of Sir Isaac Heard, impaled with that of his office, Garter King of Arms, and ensigned with the crown of a King of Arms. The whole is blazoned thus: *argent*, a cross, *gules*; on a chief *azure*, a ducal coronet, *or*, surrounded by the garter, between a lion of England and a fleur-de-lys of France; the whole impaled with a Triton, crowned, grasping in his right hand a trident, and in his left the mast of a ship; all in the sea, *proper*. On a chief *azure*, an estoile *argent*.

The *Mermaid* is the female of the last monster.

Desinit in piscem mulier formosa superne.

She is generally represented bearing a mirror and a comb.

Monstrous beasts are the unicorn, the Pegasus, the antelope, the tiger, the musimon, the dragon, the gryphon, the salamander, and the opinicus.

The *Unicorn* is a horse, tailed like a lion, and having one straight horn issuant from his forehead. He is the present sinister supporter of the Arms of the United Kingdom of Great Britain and Ireland. See him in fig. 121, *argent*, an unicorn, *sable*, name, Harling.

The *Pegasus* is none other than the winged horse known by this name to antiquity. We have given a representation of him in fig. 122, *azure*, a *Pegasus* volant, *argent*, being the Arms of the Honourable Society of the Inner Temple, London.

The *Antelope*, though bearing the name of a creature well known in zoology, is chimerical in Heraldry. The Heraldic antelope has the body of a wolf, the tail of a lion, and a tusk on its nose, like that of the rhinoceros. The Heraldic *tiger* only differs from this beast by having on its head two serrated horns, and being hoofed like a deer. If its horns project straightforward, it is called an ibex. *Argent*, an antelope, *gules*, attired and unguled, *or*, is the Arms of Antilupe. Fig. 123.

The *Musimon* is an animal supposed to be generated between the goat and the sheep. See fig. 124, the Arms of Arnold, *gules*, a musimon, *argent*.

The *Dragon* is a quadruped having the tail of a serpent, with a pair of ribbed wings. Herein he differs from the δρακῶν of antiquity, whence he derives his name. The δρακῶν was merely a large serpent. Dragons are the supporters of the Arms of the City of London. A dragon with seven heads is called a *hydra*. *Or*, a dragon passant, *gules*, is the Arms of the Empire of China. See fig. 125.

The *Gryphon* is an animal having the head, the wings, and the talons of the eagle in front, and the hinder parts of a lion. The γρὺψ of the Ancients, whence this creature has his name, was a bird. The gryphon, when rampant, with wings erect, is said to be *segreant*, or *sergreant*, probably from *surgo*; and *sable*, a *gryphon* sergreant, *or*, is the Arms of the Honourable Society of Gray's Inn, London. Fig. 126.

The *Salamander* is an animal somewhat resembling a lizard, and always represented in flames. See fig. 127, *azure*, a salamander, *proper*, the Arms of Cennino.

The *Opinicus* has the head and wings of an eagle, the body of a lion, and the tail of a camel. It is the crest of the Company of Barber-surgeons of London. See fig. 128.

Any animal may be Heraldically converted into a marine monster, by changing the lower part of the body into the tail of a fish. Thus are formed the sea-horse, sea-lion, &c. Heraldically called *horse poisson*, *lion poisson*, &c.

Monstrous birds are the allerion, the martlet, the cannet, the phœnix, the wyvern, and the cockatrice.

The *Allerion* is an eagle *sans* beak and feet.

The *Martlet* is a corruption of the French *martinette*, the small martin; it resembles a martin without legs. The French have again corrupted our word into *merlette*, which would seem to signify a little blackbird. The martlet is a very ancient bearing, and is interesting to the Englishman from the share which it sustains in the Arms of our Saxon Kings: those of Edward the Confessor (fig. 129) are blazoned *azure*, a cross flory, between five martlets, in orle, *or*.

The *Cannet* is a duck *sans* beak and feet.

The *Phœnix* is a well-known creation of ancient imagination. It is represented like an eagle, with gaudy plumage, unless the colour be expressed, and sitting on a blazing nest. A phœnix on a ducal coronet is the crest of Seymour. Fig. 130.

The *Wyvern* is a two-legged dragon; as a winged biped, he may deserve to be classed among the chimerical birds. Fig. 131 is the ancient bearing of the Vandals, quartered in the ancient Arms of Denmark and Norway: *gules*, a wyvern with wings displayed and tail nowed, *or*. The escutcheon is ensigned with the crown of Denmark.

The *Cockatrice* has the head and feet of a cock, with the wings and tail of a dragon. When the tail is terminated by the head of a dragon, he is called a *basilisk*. *Argent*, a cockatrice, *sable*, crested and jelloped, *gules*, is the bearing of Langley. Fig. 132.

Charges decorated with the heads of serpents are termed *gringolly*; of lions, *leonced*; of eagles, *aquilated*; of peacocks, *pavonated*, &c. See the Arms of Kaer, fig. 133, *gules*, a plain cross, ermine, gringolly, *proper*.

Inanimate.
Vegetables.

Of inanimate charges, we consider vegetable productions as first deserving notice, from the intermediate situation which they occupy between the rest of the inanimate world and animals.

Trees and flowers are subject to *couping* as well as animals. They are besides *blasted*, when leafless; *eradicated*, when the roots appear; *slipped*, when irregularly broken off; *pendent*, if drooping; *fructed*, if bearing fruit; *accrued*, if full grown. A wheatsheaf is called a *garb*.

Heraldic flowers, *i. e.* such flowers as have a purely Heraldic representation, are the rose, the fleur-de-lys, the trefoil, the quaterfoil, the cinkfoil, the narcissus, and the double quaterfoil.

Of the Heraldic *rose*, we have given a representation in fig. 134, the Arms of Christ Church, Oxford. *Sable*, on a cross engrailed, *argent*, a lion passant, *gules*, between four leopards' heads, *azure*; on a chief, *or*, a rose, *gules*, barded *vert*, between two Cornish choughs, *proper*.*

Of the *fleur-de-lys*, we have given some account before. Our example for this will of course be the Arms of France, *azure*, three fleur-de-lys, *or*, as represented in fig. 135. Any charge *ornamented* with fleur-de-lys (not used as charges) is called *flory*.

The remaining flowers represent different species of grass, having respectively three, four, five, six, and eight leaves. Examples occur in the following escutcheons.

Fig. 136. The trefoil. *Gules*, on a bend *argent*, three trefoils within a bordure, *vert*, the bearing of Doctors' Commons, being the arms of Dr. Harvey, the founder.

Fig. 137. The quaterfoil. *Gules*, five quaterfoils in saltire, *or*. Name, Palmer.

Fig. 138. The cinkfoil. *Or*, a chevron between three cinkfoils, *gules*, for All Souls' College, Oxford.

Fig. 139. The narcissus. *Argent*, a narcissus, *gules*. Name, Sextill.

Combination of animals and plants.

There is a curious combination of animal and plant exhibited in the Arms of the See of Hereford, fig. 140, *gules*, three leopards' heads reversed, jessant as many fleur-de-lys, *or*.

Celestial bodies.

Of all objects not possessing life the heavenly bodies will first claim our notice.

The sun is represented as a circle rayonny, containing a human face. He is usually *or*; and when this is the case, he is said to be *in his splendour*; when he is *sable*, he is *in his detriment*. We shall give a representation of a Heraldic sun in a singular coat shortly to be noticed.

The full moon, or moon *in her complement*, is a circle containing a female face, and surrounded with rectilinear rays. When *argent*, it is only necessary to say proper, or leave the colour unmentioned. When *sable*, the moon is said to be *in her detriment*. We shall exhibit her in the coat just mentioned.

An *increscent* is a horned moon, the horns being to the dexter of the escutcheon. Fig. 141, *azure*, an increscent, *argent*, is the Arms of the Turkish Empire.

A *crescent* is the same, the horns being towards the chief. See fig. 142, the Arms of Tutbury Monastery, *azure*, a saltire vair of gold and red, between four crescents, *argent*.

A *decrescent* is the same, having the horns to the sinister. See fig. 143, *azure*, a decrescent, *proper*. Name, Delaluna.

An *estoile*, or Heraldic star, has its points all wavy; if they vary from six, the number must be specified. This charge, together with the Heraldic sun and moon, is curiously exemplified in the bearing of John de Fontibus, sixth Bishop of Ely. His Arms appear in fig. 144. They are blazoned *azure*, in chief, the sun in his splendour, the moon in her complement; in base, the 7 stars, 1, 2, 1, 2, 1, *or*.

A mullet is supposed to represent a meteor, and has sometimes six, but most generally five points, all plain; when a mullet alone is mentioned it has always five points. Fig. 145, *gules*, on a chief, *argent*, two mullets, *sable*, is the Arms of the great Lord Chancellor Bacon, Baron Verulam and Viscount St. Alban's. A very similar bearing, *viz*. *argent*, on a chief, *gules*, two mullets pierced, *or*, is the Arms of St. John, Lord Bolingbroke.

A *thunderbolt* is a fantastical imitation of the ancient representation of this object. *Sable*, a thunderbolt, *or*, the pretended Arms of Scythia. Fig. 146.

Precious stones.

Of *precious stones* the only one which is strictly Heraldic is the *escarbuncle* or carbuncle, which is borne generally of eight rays, as in fig. 147, *gules*, a chief, *argent*, over all an escarbuncle of eight rays, *or*. This is the bearing of the Plantagenet family, in their representative Geoffrey, Earl of Anjou, father of Henry II. of England.

Artificial.

Artificial charges are,

1. *Ecclesiastical*. The *sacerdotal pall*, or pallium. We have an instance in fig. 148, the Arms of the See of Canterbury: *azure*, a staff in pale, *or*, bearing on its top a cross paty, *argent*, surmounted of a sacerdotal pall of the last, charged with four other like crosses fitchy, sable, edged and fringed of the second. Of mitres, crosiers, &c. we shall treat separately.

2. *Honourable*. This head would embrace all coronets, insignia, &c., but these will be treated separately. We shall therefore only notice one which is more especially confined to the escutcheon, *viz*. the *annulet*, a plain ring as in fig. 149. The Arms of the German Empire, now those of Austria, are *or*, on an eagle with two heads displayed, *sable*, each head within an annulet, *argent*, grasping with the dexter claw two swords, with the sinister a mound, an escutcheon bearing *gules*, a fess *argent*, impaled with *gules*, a tower *argent*.

3. *Military*. Heraldry having taken its rise entirely from military distinctions, is necessarily rich in military emblems; and its wealth has been especially augmented by the tournaments. Helmets, considered as distinctions of rank, will fall most properly under the division of marshalling.* But those military implements which occur as peculiar bearings on the escutcheon, may well be considered here. The *chaplet* somewhat resembles the crowns which have been already delineated. Fig. 150, *argent*, three chaplets, *vert*, are the Arms of Richardson.

The *morion* (quasi *Morian*, or Moorish, being used by that people) is a steel cap, represented in fig. 151, the Arms of Brudenell, *argent*, a chevron, *gules*, between three morions, *azure*. The Heraldic morion differs considerably from the article of defensive armour generally so called.

The tilting staff, used in jousts and martial exercises, contributes, with its parts, to the resources of Heraldry. It exactly resembles a lance, except that it terminates in what is termed a cronel, or coronal. We give a representation of one, after Gwillim, with the references. A is the *bur*, or rest for the hand. B, the place of the hand. C is the *vamplet*, a movable guard to the hand. D is the cronel. Fig. 152.

Fig. 153 is blazoned thus: *argent*, a chevron between three rests, *gules*, for Arthur of Clepton. The bearing is supposed to represent the rests into which the tilting staves were fixed; but they are by some armorists called *clarions*.

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* The author of the *Synopsis of Heraldry* observes, "in this one example, you have all the common colours in Heraldry, and accidents either of lines, or things charged with or interposed, by ordinaries or ordinary charges."

* It may be worth observing, that when "a helmet" only is mentioned in blazon, it is always *an esquire's*.

A *pheon* is supposed to be the iron head (*ferrum*) of a javelin or arrow. It is a common bearing in armory. See fig. 154, *or*, a pheon, *azure*, for Sidney.

A *sweep*, or *balista*, is not, in strictness, exclusively Heraldic, yet from the rarity of its delineation, we may be allowed to exemplify it in the arms of Magnall, fig. 155, *argent*, a sweep, *azure*, charged with a stone, *or*. When a sword bears any charge on its point, it is said to be *enfiled* with it; and when any military instrument is spotted with blood, it is said to be *imbrued*.

4. *Pertaining to the Arts liberal.* The *billet*, supposed to be the representation of a folded letter. It is a long, rectangular parallelogram, placed paleways on the escutcheon. When the number of billets in a coat exceeds ten, the coat is called *billety*. See representation in fig. 156, the Arms of the Kingdom of the Netherlands, *azure*, billety, a lion rampant, *or*.

5. *Pertaining to clothing.* Under this head we may class the *manch*, (*manche*, Fr. sleeve,) a device of not unfrequent occurrence. It represents a flowing sleeve. See fig. 157, the Arms of Hastings, *or*, a manch, *gules*.

A shoe, called by the Irish a *brogue*, is sometimes found in armory, as in fig. 158, the Arms of Arthur of Ireland, *gules*, a chevron between three brogues, *or*.

6. *Miscellaneous.*

These we shall class alphabetically, simply referring the reader to the examples in the plates, as many of these devices cannot be clearly defined.

Fig. 159. *Gules*, three *arches*, *argent*, masoned, *sable;* the capitals and bases *or*. Name, Arches.

Fig. 160. *Or*, three *barnacles*, *gules*. Name, Barnack. The barnacle is supposed to be an instrument for holding and curbing horses.

Fig. 161. *Sable*, three fire *beacons*, *or*, inflamed, *proper*. Name, Dawntry.

Fig. 162. *Gules*, three *birdbolts*, *argent*. Name, Bottlesham. The birdbolt is represented diversely, as we have shown in this example; but one mode only ought to be exhibited in drawing the Arms.

Fig. 163. *Azure*, on a chevron, between three managebits, *argent*, three *bosses*, *sable*, the Arms of the Lorimers of London.

Fig. 164. *Argent*, three *boterols*, *gules*, the Arms of the Duchy of Angria. They are surmounted by the electoral bonnet. The boterol is the tag of a scabbard.

Fig. 165. *Gules*, a *Katharine wheel*, *or*, the Arms of Katharine Hall, Cambridge.

Fig. 166. *Gules*, three *chessrooks*, *argent*. Name, Walsingham.

Fig. 167. A *crampet;* the badge of Delawar. It has the same signification as the boterol.

Fig. 168. *Argent*, a heart, *proper*, within a *fetterlock*, *sable*, on a chief, *azure*, three boars' heads of the field. Name, Lockhart. An ancestor of this family carried the heart of Robert Bruce to Palestine; whence the bearing.

Fig. 169. *Sable*, a chevron between three *fleams*, *argent*, the Arms of the Surgeons of London. The fleam is an old kind of lancet.

Fig. 170. Per pale, *gules* and *azure*, a *fleece*, *or*, hooped and ringed; in chief, a lion passant gardant, between two fleur-de-lys of the second. Or the latter part may be blazoned, a lion of England between two fleur-de-lys of France. The Arms of the town of Tavistock.

Fig. 171. A *gurges*, *proper*. Name, Gorges. Water is Heraldically represented by equal alternate spaces of *azure* and *argent*. The spiral form indicates a whirlpool. It is enough, therefore, to blazon this *proper;* if the colours were any other they should be particularized.

Fig. 172. *Azure*, on a chevron between three *hatbands*, *or*, three *merillons*, *sable*, the Arms of the hatband makers of London.

Fig. 173. *Argent*, a *hayfork* between three mullets, *sable*, the Arms of Burton-Conyngham, Marquess of Conyngham.

Fig. 174. *Gules*, a chevron between three *Bowen's knots*, *argent*. Name, Bowen.

Fig. 175. *Dacre's knot.* The badge of Dacre.

Fig. 176. *Harrington's knot.* The badge of Harrington.

Fig. 177. *Lacy's knot.* The badge of Lacy.

Fig. 178. *Gules*, a tower, *argent*, masoned, *sable*, between two *Stafford knots* in chief, and a lion passant gardant in base, *or*, the Arms of the town of Stafford.

Fig. 179. *Argent*, a cardinal's hat, *gules*, the strings in *truelove*. These Arms are sometimes assigned to Sclavonia. But others are sometimes used.

Fig. 180. *Wake's knot.* The crest of Wake.

Fig. 181. *Gules*, a *lure*, *argent*. The Arms of Warre. The lure was thrown up in the air to attract the hawk back.

Fig. 182. *Argent*, a *lymphad*, *sable*, the Arms of the Earldom of the Isle of Arran. The lymphad is a small coasting vessel.

Fig. 183. *Argent*, a chevron between three *milrinds*, *sable*. Name, James, of Surrey. Three ordinary representations of the milrind are here given, although one only ought to be preserved in drawing the Arms.

Fig. 184. Per pale, *azure* and *gules*, two *Palmers' staffs* in saltire, *or*, the Arms of the Priory of New Nantwich. Two representations are here given of the Palmer's staff, although one only should be preserved in delineating the Arms.

Fig. 185. *Or*, *papillone*, *gules*. Name Grimball.

Fig. 186. *Azure*, three *pennyyard pence*, *proper*. Name, Spence.

Fig. 187. *Gules*, a *portcullis*, *argent*, nailed and pointed, *azure*, the arms of the Borough of Harwich.

Fig. 188. *Azure*, on a bend, *gules*, two garbs, *or*, on a chief, *sable*, a *Tau*, *argent*, the Arms of Thavies Inn, London.

Fig. 189. *Argent*, *treilly*, *gules*, nailed, *or*. Name, Bardoenche.

Fig. 190. *Sable*, on a bend between two *turrets*, *argent*, three pheons, *gules*. On a chief, *or*, a lion passant gardant, between two lozenges, *azure*. Name, Johnson.

Fig. 191. *Argent*, a cross engrailed, *gules*, between four *water bougets*, *sable*. Name, Bourchier. Four varieties of this charge are given in the example for the sake of illustration; but one only should be employed in the drawing. That in the dexter base is the most usual.

Fig. 192. *Argent*, a *wreath*, or torse, *argent* and *sable*, garnished with four hawks' bells, *or*. Name, Jocelyn.

Fig. 193. *Argent*, a fess *wreathy*, *azure* and *gules*. Name, Carmichael.

We have now, we believe, offered the reader a sufficient number of rules and examples in blazonry to enable him to blazon any escutcheon which may present itself. It is true that we have not crowded our plates with "glaziers' nippers," "hempbreaks," "woolcarders," &c. although those, and many similar implements, are occasionally borne in Arms. Such devices undergo no change in the crucible of Heraldry; it is not, therefore, necessary to notice them here. Ignorance of their form is not Heraldic but technical ignorance; and as the adoptive power of Heraldry is literally infinite, it would be impossible to trace her footsteps universally.

II. Marshalling.

We are now, therefore, ready to enter on that branch of the system which is called *Marshalling*. As blazonry teaches the *description* of coat armour, so Marshalling is concerned with the *arrangement* of it. Blazonry furnishes the nomenclature, Marshalling the *rationale*, of Heraldry. Degrees of rank and affinity are distinguished by this department of the theory; and while the family coat remains unaltered, Marshalling discovers whether its peculiar owner is single or married, what is his distance from the inheritance, what is his rank in the state, and what honours or disgraces he has received. To Marshalling, therefore, Heraldry is indebted for most of its interest, and all its utility.

Arms in general are divided into perfect and imperfect. Perfect are, 1. Abstract, or warranted by regular descent. 2. Terminal, belonging to brethren of the right line. 3. Collateral, borne by brethren of the heir male. 4. Fixal, in third degree by right line of male heirs. Imperfect are, 1. Granted by the King with a lordship. 2. The gift of the King derived by a Herald. 3. The ensign of a Saracen won in field. 4. Heir female of elder branch. 5. Arms of bastardy.

In treating this subject we shall discourse, I. On family distinctions. II. On those of rank. III. On those of honour. IV. On abatements. V. On ensigns.

Family distinctions. Differences.

I. The most simple family distinctions are those which are technically termed *differences*.

Ordinaries appear to have been anciently used as differences. But no traces of this practice reducible to any regularity are to be met with. The bordure was formerly extensively employed in differencing the members of a family. The eldest son bore the Arms alone; the other members added a bordure, ensigned with some expressive Device. But these Devices were not of general application, and were only intelligible to those previously acquainted with them. Whereas the differences now in use, are, under the same circumstances, *always the same;* except only in the Royal Family.

Bordures were formerly especially in use in the Royal Family: partly for differencing collateral branches, and not unfrequently illegitimate descendants. For the latter purpose, bordures *compony* were commonly used. Hamlin Plantagenet, natural brother of Henry II., bore for difference a bordure, *gules*, enurny of six lioncels passant, *or*. Henry Fitzroy, Duke of Richmond and Somerset, illegitimate son of Henry VIII., bore a bordure quarterly, perflew of ermine and countercompony, *or* and *azure*. The present Duke of Beaufort, who is descended from a natural son of Henry Beaufort, Duke of Somerset, grandson of John of Gaunt, bears round the Arms of that Prince a bordure compony, *argent* and *azure;* and the present Duke of Richmond, descendant of a natural son of Charles II., bears round the Arms of that Monarch a bordure compony, *gules* and *argent;* the latter spaces being ensigned with roses of the first. " A chevron is never to be seen in the armorial ensigns of Kings and Princes, nor as a brisure in the arms of their descendants." (Peacham *apud* Nisbet.)

" Marks of cadency,"* says Mr. Dallaway, (sec. 7.) "are discriminated from each other by nine several modes. 1. Change of the tincture of the field. 2. Of the essential figures. 3. By dividing the field by various partition lines. 4. By altering the position of the figures. 5. By diminishing their number. 6. By increasing them. 7. By adding others to the principal. 8. By quartering. 9. By transposing." But all these variations took place according to no settled rules. In illustration of this remark we may observe, that of the five sons of Arnold, Count of Arescot, the first bore his paternal arms,

paternal arms,	*or*, three fleur-de-lys,	*sable*.
The second	*gules*	*argent*.
The third	*argent*	*gules*.
The fourth	*argent*	*sable*.
The fifth	*gules*	*or*.

Marks of cadency.

The present mode of differencing Houses is by what are called *marks of filiation or cadency*. These are small charges, but placed in the most conspicuous situation of the shield, and of whatever metal, colour, or fur, may be best adapted for discovering them to the eye. The eldest son bears a label of three points. Some ancient Heralds assign him a label of five points in the life of his grandfather, and one of three afterwards. But this practice is seldom employed at present; and the eldest son frequently never takes up his difference at all. The second son bears for his difference a crescent; the third, a mullet; the fourth, a martlet; the fifth, an annulet; the sixth, a fleur-de-lys; the seventh, a rose; the eighth, a cross moline; the ninth, a double quaterfoil. The second House, or second son's family, bear, respectively, the eldest a crescent ensigned with a label; the second, the same ensigned with a crescent; the third, the same ensigned with a mullet, &c. and so throughout. The third House bear respectively, the eldest a mullet ensigned with a label; the second, the same ensigned with a crescent, &c. &c. in like manner. These distinctions never belong to females, except in the Royal Family, where the whole system of brisures differs. The Royal Family do not bear the Royal Arms of right; they must be granted by the King, and registered in the College of Arms. Hence the frequency of bordures and other differences, formerly attached to the Royal Arms; and hence, too, the vacillation of modern differences in this family. All the brisures of the Royal Family are labels, which extend to females. Those of the present family, which we have engraved, were settled in the last reign, and can readily be blazoned by the student from what has been already delivered.

When these brisures were invented is not easy to say. It is evident, however, that they were in use in the time of Edward I., as appears from that truly curious document, the Roll of Karlaverock, wherein it is asserted that Maurice de Berkeley bore a label because his father was alive.

> *E Morices de Berkelee,*
> *Ki compaignis fu de cele alee,*
> *Baniere de vermeille cum sanc,*
> *Croissillie o un chievron blanc,*
> *Ou un* label *de asur avoit*
> Porce que ces peres vivoit.

The *Book of St. Albans* says: " ther be vj differences in armys. ij for the excellent and iiij for the nobles. Labell and *embordurynq* for lordis. Jemews, molettys, flowre delyce and quyntfoyles for thee nobles."

Females bear their paternal Arms on a lozenge before marriage; afterwards they bear them impaled with those of the husband on the sinister side, which is called *Impalement per Baron et Femme.* Widows bear the

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* By marks of cadency, Mr. Dallaway here intends what we call *differences*.

Arms of their husbands, impaled with their own, as when married, on a lozenge. When a widower marries, he marshals his own coat between the coats of his wives; his former wife's on the dexter. A most remarkable example is given by Gwillim in the Arms of Sir Gervase Clifton, who married *seven* times: the Arms of his wives are marshalled in seven compartments, four on the dexter, and three on the sinister side of his own coat.

In cases where the husband or wife enjoys some *peculiar* distinction, as when the husband is an Archbishop, Bishop, King of Arms, or Knight of some military order, or where the husband is of rank inferior to the wife, his escutcheon is placed on the dexter side; containing, if a Bishop, or King of Arms, the Arms of his See or office impaled with his own; if otherwise, his own Arms, decorated with his peculiar additions, if any; on the sinister the wife's escutcheon is placed, containing the Arms of her husband impaled with her own, and bearing her peculiar distinctions, if such there be. Where the wife was of noble blood, and the husband a commoner, it was formerly sometimes customary to marshal the wife's Arms to the dexter; but this is now obsolete.

Formerly, the husband and wife's Arms were *impaled by dimidiation;* that is, the dexter half of the husband's coat was impaled with the sinister of the wife's. Fig. 193 represents the seal of Margaret, second Queen of Edward I., which affords a specimen of this species of conjunction. In France this custom prevailed up to the time of the Revolution; but in England, it has been long since discontinued for the soundest reasons. In many cases it would have the effect of totally changing the Arms, and, in most, it would render those of each party unintelligible. For instance, the Arms of Stanhope are *quarterly, ermine and gules;* those of Waldegrave, are *party per pale, argent and gules;* the impalement of these coats *per baron et femme,* would destroy every vestige of both, leaving a new perfect coat, *gules, a quarter ermine.* Cantons and quarters would perish in the bearing of the female; many Heraldic animals would become equivocal; and where Arms were quartered, some of the coats would be totally lost. But before Heraldry had become systematized, such alterations were not deemed important, as conjunctions apparently more incongruous were sometimes made. Henry II., whose Arms were *gules,* two leopards passant gardant, in pale, *or,* on his marriage with Eleanor of Aquitain, whose Arms were *gules,* a leopard passant gardant *or,* united the two bearings into *gules,* three leopards passant gardant, in pale, *or.* And Philip the Bold, Duke of Burgundy, bore his own Arms dimidiated, and those of his wife in full.

The bordure and tressure may be considered the only cases in which the early practice is not entirely repealed; when these ordinaries are impaled, they are cut off on the side of the impalement.

Where the wife is an heiress or coheiress, her Arms are borne on an inescutcheon over those of her husband. In this case the inescutcheon takes the name of an *escutcheon of pretence.* But this arrangement is not allowed until the death of her father. In some ancient coats we find the Arms of the husband and wife *quarterly,* and even those of the wife in the first quarter. This is where a man receives a barony or any feudal tenure in right of his wife. And the same thing takes place wherever a surname is added. Thus the present Duke of Marlborough, whose original name was Spencer, having taken the name of Churchill, bears the coats of Churchill and Spencer quarterly.

Where the father can place his wife's Arms on an escutcheon of pretence, the children may quarter them with the paternal coat; and from a series of descents of this description arises that abundance of quarterings which may be noticed in the shields of some noble families.

When there are only two coats to be quartered, the first in precedence or dignity occupies the first and third quarter; and the other quarters are supplied by the latter. If the number of coats be *odd,* the last quarter is generally supplied by the *leading* bearing, although foreign Heralds sometimes make a point in the base of the shield, which reduces the quartering to an odd number. This mode of marshalling enters into the Arms of Hanover, which form part of the bearings of the British Sovereign, where Brunswick, Luneburg, and Saxony are thus arranged.

When a widower marries, having no male issue by his late wife, his male issue by the second wife become, of course, his heirs; but a daughter by the former wife is heir to the mother; to indicate which she bears her maternal Arms, with all their quarterings, if any there be, with her paternal Arms on a canton. These rules afford a sufficiently clear outline of the general system of expressing alliances. Its refinements may be studied in "rules for the dewe quarteringe of Armes," a MS. in the Herald's College attributed to Glover, "the most diligent and skilful of his contemporaries," as he is called by Mr. Dallaway, who has published the "rules" in his *Inquiries into the Origin and Progress of the Science of Heraldry in England,* sec. 7.

These rules, however, do not apply to the reigning posterity of Sovereign Princes. The Sovereign, in assuming the National bearing, foregoes his private Arms. The quarterings of National Arms are regulated purely by National causes. The Sovereign's consort bears her Arms on a shield to the sinister of her husband's. But they are never quartered by succeeding Monarchs, as the effect of such a permission would be eventually to destroy international distinctions.

When a State consists of a number of *united* States, it is usual for the Prince to quarter their Arms in the order of their importance. When England and Scotland were first united, the Arms of those two Countries were *impaled* in the first quarter of the shield of Great Britain; an unusual, but significant arrangement, by which a marriage between the nations were implied. This distribution is now discontinued, and the Arms of Scotland form one of the quarterings of the shield of Great Britian. But where a Prince governs several *independent* nations, it is usual to put the Arms of the less considerable on escutcheons of pretence, ensigned with their proper crown or other emblem of Sovereignty. Thus the King of Great Britain, when Elector of Hanover, bore the Arms of Hanover on an escutcheon of pretence, surmounted of the electoral bonnet; and now as King of Hanover, he bears the same, but surmounted of the crown royal. This rule, however, has not been always minutely observed; as the Arms of Ireland before the Union, were not marshalled on an escutcheon of pretence, but formed, as they do now, one of the regular quarterings of the whole national escutcheon; and the same may be said of some continental bearings. "Arms of special concession are those of the Sovereign, or parts of them which cannot be granted by Heralds without a warrant from the Sovereign. And, secondly, such Arms take place before all other sorts of Arms. And, thirdly, Heralds are to record them in their registers, and to pass them on all solemnities."*

Hatchments and funeral escutcheons.

Hatchments and funeral escutcheons enter so much into the province of Heraldry that it will be necessary to notice them here. A funeral achievement,† vulgarly called hatchment, is a square piece of board or other material, the border of which is painted black, and which is suspended from one of its corners against the front of the house of a deceased person, where, after remaining one year, it is usually removed into the Parish church. The centre is filled up with the Arms of the deceased, painted according to rules hereafter to be set down. A funeral escutcheon is an oblong piece of cloth, similarly bordered, and hung lengthways on horses and funeral decorations. The centre is also occupied with the Arms of the deceased, and is subject to the same rules as the hatchment, which follow.

If the deceased be a bachelor, maid, widow, or widower, the whole ground is painted black. If a husband, the dexter half of the ground is painted black; if a wife, the sinister.

If the second wife of a widower, or second husband of a widow, then those parts of the ground which lie round the Arms of the deceased are painted black, and the rest white.

The black ground never touches the Arms of *an office;* because that is not in its nature mortal.

A little white space is also sometimes left for the crest when it is of any dark colour. When the deceased is the last of the family, the death's head supplies the crest.

Distinctions of rank.

2. All ranks are not *minutely* distinguished by Heraldic symbols. We shall give, however, the degrees of precedency as established in England, specifying as we proceed, those which are particularly noticed by Heraldry. But as crowns, coronets, and helmets are among the most prominent distinctions of rank, it may be useful first to say a few words on the manner of arranging them.

As the crest should always be placed on the helmet, either on a wreath, small ducal coronet, or chapeau, which are considered as making part of the crest; so, where a helmet and coronet are to be used together, the helmet should always be placed uppermost; but in the cases of the Monarch and Prince of Wales, who bear crowns, the crown is placed uppermost, and the crest situated above it, without any intervening object. The crests of the rest of the Royal Family are placed on small Prince's coronets without caps, instead of wreaths. All helmets may be adorned with what are called *mantlings* or *lambrequins.* The terms are commonly used indiscriminately, but are not synonymous in their original acceptation. The mantling was originally a flowing piece of cloth encompassing the back of the helmet; the lambrequin represents the same cloth considerably hacked in encounters, and fluttering in all directions. The latter is most usually employed by modern Heraldry painters. It was formerly the custom to represent *all* lambrequins *gules, doubled* (*i. e.* lined) white,* except those of the Sovereign, which were *or,* doubled ermine. But the College of Arms have lately decided in Chapter that the two first tinctures named in the blazon of the escutcheon should form those of the lambrequins; the metal always being inside. But if a fur be one of the two first tinctures, then the colour predominating in the fur is to stand instead of the fur itself. In the case of a field vair, the lambrequins should be *argent* and *azure;* and, in general, where equal tinctures compose the field, the lambrequins should exhibit those tinctures. The same rules apply to the composition of the wreath; which should always begin with metal, and end with colour.†

Mantling.

There is a kind of mantling much in use with coach-painters, which, though supported by the authority of Edmondson, we cannot but deem unclassical. This mantling embraces the whole achievement, and if belonging to the Sovereign, is of gold lined with ermine; if to a Peer, crimson velvet lined in like manner; if to a Commoner, the same lined with white satin. At Edmondson's suggestion some of the Peerage agreed to adopt the following distinctions in their mantlings, corresponding to those adopted on their Coronation robes; a Baron was to have two timbers of ermine; a Viscount, two and a half; an Earl, three; a Marquess three and a half; &c.

If two or more crests are to be placed on the same escutcheon (which is allowable where Arms are quartered) they must be set on suitable helmets; the same rule and practice are observed when a Sovereign governs several *independent* Monarchies. In these cases, if the number of helmets be even, the dexter half must be turned to the sinister, and *vice versâ;* if odd, the centre helmet must be *affronty*; or full faced, and the others as before. In the last case, the helmet of the family, or leading dignity, occupies the centre; and those of nearest dignity are marshalled nearest, dexter and sinister *alternately;* otherwise the dexter is the place of honour, and the inferior crests are marshalled to the sinister.

Precedency of men.

The following are commonly received as the degrees of precedency among men.

1. The King. His armorial ensigns as Sovereign are the crown of the United Kingdom; and a full faced helmet of six bars, all of gold, damasked *gules* between the bars. It is not usual, but Heraldic and allowable, to marshal behind the Arms of the Sovereign the different sceptres to which he is entitled. The crown borne in Arms is that with which the Coronation ceremony is performed. That of Edward the Confessor was supposed to be preserved in Westminster Abbey until the time of Charles I. The crown then used was sold by the rebels. At the Restoration a new crown was made, consisting of a rim of jewelled gold, resting on a border of ermine. On this rim arose four crosses paty, and four fleur-de-lys alternately from the crosses. From each cross ascended a richly jewelled arch, and at the intersection of these arches was affixed a pedestal supporting a mound, on which stood a cross of gold richly ornamented with precious stones. The cap

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[*] Nisbet, *Essay on Armoury,* p. 146.

[†] The word achievement, separately taken, signifies a *whole* armorial bearing; escutcheon, helmet, crest, supporters, &c. &c. The word hatchment, however, has been restricted by custom to an achievement painted for funeral purposes.

[*] White in the interior of mantlings was not blazoned *argent,* not being taken for a metal, but a fur; the skin of the lituit. See Gwillim, sec. 1. ch. iii. but the modern system has changed the nature of the blazon.

[†] Yet fur was certainly used in doublings formerly; witness that very remarkable instance adduced by Gwillim, ch. v. sec. 6. "I find in the church of Gravenest, in the county of Bedford, in a window, a mantle *sable,* doubled *verrey,*" [vair, or vairy.]

within the crown is of purple velvet, lined with white taffeta, and turned up with ermine. The King and Princes use a full-faced helmet of gold, with six bars, and damasked with crimson.

2. The Prince of Wales. He is distinguished by a coronet, differing only from the imperial crown in being closed with *two* arches only, springing from opposite crosses. He also bears as a badge a plume of feathers surrounded by an open coronet of alternate fleur-de-lys and crosses, and bound by a riband, bearing the motto *Ich dien;* in commemoration of the capture of John, King of Bohemia, who bore this device, by Edward the Black Prince, at the battle of Crecy. The Prince of Wales bears also a mark of filiation, as assigned by the King, over the Royal arms.

3. Princes of the Blood according to seniority. Their coronets resemble that of the Prince of Wales, except that they are not closed.

4. The King's brothers.

5. The King's uncles.

6. The King's grandsons.

7. The King's brothers' or sisters' sons.

8. Husbands of Princesses.

'All these (except the latter, who use their paternal distinction) use a coronet of four alternate crosses paty, and four strawberry leaves.

9. The Archbishop of Canterbury, Lord Primate of all England. He impales the Arms of his See with his own. He bears a mitre, as represented in fig. 147, but not surrounded with a ducal coronet, as some writers pretend. The crosier, a kind of sceptre or *lituus*, terminating in a curve resembling a shepherd's crook, and emblematical of his pastoral charge, is not necessary to the delineation of Episcopal Arms, but is frequently found at the back of the Bishop's shield, as in fig. 147, as also the Bishop's staff.

10. The Lord High Chancellor, or Lord Keeper of the Great Seal. He bears behind his shield in saltire two maces of England, as in fig. 144.

11. The Archbishop of York, Primate of England. As the Archbishop of Canterbury.

12. Lord High Treasurer.

13. Lord President of the Privy Council.

14. Lord Privy Seal.

15. Lord High Constable.

16. Earl Marshal. He bears behind his escutcheon two bastons in saltire, as in fig. 52.

17. Lord High Admiral.

18. Lord Steward of the Household.

19. Lord Chamberlain of the Household.

The last five take precedence of all of their degree; *i. e.* if Dukes, they precede all Dukes; if Marquesses, all Marquesses, &c.

20. Dukes according to their patents. The ducal coronet is ornamented with eight strawberry leaves, five of which are seen in Heraldic drawings. Crests are sometimes placed on what is called a ducal coronet, instead of on a wreath; in this case the strawberry leaves are supposed to be four in number, and three are visible in the drawing. See the coronet in fig. 52. Dukes, and all Peers, are entitled to a steel helmet in profile, with bars of gold, damasked crimson.

21. Marquesses according to their patents. The Marquess's coronet is adorned with four alternate strawberry leaves, and as many pearls. In drawings, three of the former, and two of the latter, are exhibited. See fig. 172.

22. Dukes' eldest sons.

23. Earls according to their patents. Earls are not supposed to have always used their present coronets. The most ancient instance of an Earl using a coronet at all is, according to Sandford, John of Eltham, Earl of Cornwall, on whose monument in Westminster Abbey it is represented, composed of greater and lesser leaves. But the present Earl's coronet is ornamented with eight pearls, raised on pyramidal slips of gold, alternating with eight strawberry leaves. See it in fig. 131. Before the introduction of the coronet, the inferior Nobility wore a chapeau, or cap of maintenance, represented in the Arms of Abtot, Earl of Worcester, fig. 99.

24. Marquesses' eldest sons.

25. Dukes' younger sons.

26. Viscounts according to their patents. The Viscount's coronet is adorned with sixteen pearls, nine of which appear. This canon we lay down on the authority of the Earl Marshal's order at the Coronation of George III. The usual representation, however, contains seven pearls only. We have shown it in the Arms of Lord Bacon, but this is an anachronism. Fig. 144.

27. Earls' eldest sons.

28. Marquesses' younger sons.

29. The Bishop of London. His Heraldic distinctions as the Archbishop of Canterbury.

30. The Bishop of Durham. His mitre is surrounded by a ducal coronet, in token that he is a Prince Palatine. He impales the Arms of his See.

31. The Bishop of Winchester. He is Prelate of the Order of the Garter. He therefore wears the distinctions of that Order. His Arms, impaled with those of his See, are surrounded by the Garter, which is of blue, bearing in gold the motto *Honi soit qui mal y pense.*

32. Bishops according to priority of consecration. The Bishop's distinctions are as those of the Archbishop of Canterbury. If a Bishop be principal Secretary of State, he takes precedence of all other Bishops, unless they hold a more elevated station in the Royal service.

33. Barons according to their patents. Till the time of Charles II. the Barons wore a plain cap of crimson velvet faced with ermine. Since, they have borne a coronet, ornamented with six pearls, four of which appear in drawings. If a Baron be principal Secretary of State, he takes precedence of other Barons, unless they hold higher situations.

34. Speaker of the House of Commons.

35. Viscounts' eldest sons.

36. Earls' younger sons.

37. Barons' eldest sons.

38. Knights of the Garter. See their distinctions under the Bishop of Winchester. All Knights whatsoever are entitled to bear a steel helmet, open, without bars, and damasked crimson. See fig. 153.

39. Privy Councillors.

40. Chancellor of the Exchequer.

41. Chancellor of the Duchy of Lancaster.

42. Lord Chief Justice of the King's Bench.

43. Vice Chancellor

44. Master of the Rolls.

45. Lord Chief Justice of the Common Pleas.

46. Lord Chief Baron of the Exchequer.

47. Judges and Barons of the Exchequer, of the degree of the Coif, by seniority.

48. Bannerets made by the King in person. This was the highest rank in ancient Chivalry. The ordinary Knight, a Knight *Bachelor*, (*bas-chevalier*,) bore in the

field a pennon, or long streaming flag, on the end of his lance. On occasions of remarkable prowess, the Monarch summoned the Knight to his side, and, cutting off the long streaming part of the pennon, converted it into a square flag, or banner, which the Knight ever after bore, and was termed a Knight Banneret.

49. Viscounts' younger sons.

50. Barons' younger sons.

51. Baronets. Baronets bear, as Knights, an open helmet of steel, without bars, damasked crimson. English and Irish Baronets also bear in the dexter or middle chief, or at the fess point, a small escutcheon, *argent*, ensigned with a sinister hand erect, apaumy, *gules*. See fig. 29. This is called the badge of Ulster. Baronets were created by James I. during the troubles in Ireland, when the Province of Ulster was, more especially, in a state of insubordination. They offered their lives, property, &c. for the defence of the Kingdom. Originally their number was but 200, but since it has been unlimited. Baronets were also created by Charles I. in pursuance of his father's plan, in order to encourage the colonization of the Province of Nova Scotia; these Baronets bear what is called the badge of Nova Scotia, *viz*. an escutcheon, borne as by the Baronets of England and Ireland, *argent*, a saltire *azure*, surmounted by an inescutcheon of Scotland, royally crowned.

52. Bannerets not made by the King in person.

53. Knights Grand Crosses of the Bath. They bear their arms encircled with a red riband, bearing in gold the motto, *Tria juncta in uno*. The collar and jewel of the Order may be added. See 38.

54. Knights Commanders of the Bath. See 38.

55. Knights Bachelors. See 38.

56. Companions of the Bath.

57. Eldest sons of the younger sons of Peers.

58. Baronets' eldest sons.

59. Knights of the Garter's eldest sons.

60. Bannerets' eldest sons.

61. Knights of the Bath's eldest sons.

62. Knights' eldest sons.

63. Baronets' younger sons.

64. Esquires of the King's body. All Esquires use a helmet of steel in profile with the visor closed. See fig. 113.

65. Gentlemen of the Privy Chamber.

66. Esquires of the Knights of the Bath. See 64.

67. Esquires by creation. See 64.

68. Esquires by office. Kings of Arms, Heralds, and Pursuivants are Esquires by office. If an inferior Heraldic officer be a Knight, the superior still takes precedence. The costume of these officers is a tabard of the Arms of the Sovereign; that of the Kings is made of embroidered velvet; that of the Heralds, of satin; that of the Pursuivants, of sarcenet. The Kings wear a crown, as represented in fig. 110, composed of a circlet of sixteen acanthus leaves, oak leaves, or feathers, (for respecting what they are, authors differ,) nine of which are visible in painting. Round it is inscribed *Miserere mei, Deus, secundum magnam misericordiam tuam*. Both Kings and Heralds wear a collar of SS; on this are two portcullises of silver gilt for the Kings, and of plain silver for the Heralds. On the breast is suspended the Union Badge, and on the back the White Horse of Hanover. The Pursuivants have no collars. Each King has Arms of office, which always consist of *argent*, a St. George's cross, but the chiefs vary in the following manner; Garter, *azure*, within a Garter of the Order, between a lion of England and a fleur-de-lys of France, a ducal coronet, *or*. Clarenceux, *gules*, a lion of England crowned, *or*. Norroy, per pale, *azure* and *gules*, a lion of England crowned between a fleur-de-lys and a key, *or*. See 64.

Marshalling.

69. Younger sons of Knights of the Garter.

70. Younger sons of Bannerets.

71. Younger sons of Knights of the Bath.

72. Younger sons of Knights Bachelors.

73. Gentlemen entitled to bear arms.

Precedency of women.

The degrees of Precedency among females are as follows:

1. The Queen. Her crown is that of the King. And in general it may be observed, that the coronets of females are those of the corresponding dignity among men. Helmets never accompany female bearings.

2. The Princess of Wales.

3. King's daughters.

4. Wives of the King's sons.

5. Wives of the King's brothers.

6. Wives of the King's uncles.

7. The King's grandaughters.

8. Wives of the eldest sons of Royal Dukes.

9. Daughters of Royal Dukes.

10. Wives of the King's brothers' or sisters' sons.

11. Duchesses.

12. Marchionesses.

13. Wives of the eldest sons of Dukes.

14. Daughters of Dukes.

15. Countesses.

16. Wives of the eldest sons of Marquesses.

17. Daughters of Marquesses.

18. Wives of the younger sons of Dukes.

19. Viscountesses.

20. Wives of the eldest sons of Earls.

21. Daughters of Earls.

22. Wives of the younger sons of Marquesses.

23. Baronesses.

24. Wives of the eldest sons of Viscounts.

25. Daughters of Viscounts.

26. Wives of the younger sons of Earls.

27. Wives of the eldest sons of Barons.

28. Daughters of Barons.

29. Maids of Honour.

30. Wives of the younger sons of Viscounts.

31. Wives of the younger sons of Barons.

32. Wives of Baronets.

33. Wives of Knights of the Garter.

34. Wives of Bannerets.

35. Wives of Knights of the Bath.

36. Wives of Knights Bachelors.

37. Wives of the eldest sons of the younger sons of Peers.

38. Wives of the eldest sons of Baronets.

39. Daughters of Baronets.

40. Wives of the eldest sons of Knights of the Garter.

41. Daughters of Knights of the Garter.

42. Wives of the eldest sons of Bannerets.

43. Daughters of Bannerets.

44. Wives of the eldest sons of Knights of the Bath.

45. Daughters of Knights of the Bath.

46. Wives of the eldest sons of Knights Bachelors.

47. Daughters of Knights Bachelors.

48. Wives of the younger sons of Baronets.

49. Daughters of Knights.

50. Wives of the Esquires of the King's body.

51. Wives of the Esquires to the Knights of the Bath.

aldry.
tements

52. Wives of Esquires by creation.
53. Wives of Esquires by office.
54. Wives of the younger sons of Knights of the Garter.
55. Wives of the younger sons of Bannerets.
56. Wives of the younger sons of Knights of the Bath.
57. Wives of the younger sons of Knights Bachelors.
58. Wives of Gentlemen entitled to bear arms.
59. Daughters of Esquires entitled to bear arms.
60. Daughters of Gentlemen entitled to bear arms.

3. The crowns mentioned in the early Historical part of this Essay are distinctions still in use. Their application has been already noticed. They are marshalled above the helmet, coronet, &c. but usually below the crest.

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s of
our.

The Arms of the Sovereign, or part thereof, are sometimes allowed to be borne as marks of peculiar favour. Richard II. is said to be the first who granted Arms of augmentation. Ordinaries, too, are added, of which the most usual are the chief and the canton. These ordinaries are generally ensigned with some significant device, or a portion of the Royal Arms as before. Thus Lord Nelson's paternal coat was augmented by a chief wavy *argent*, bearing a palm-tree between a ship at sea and a castle, all *proper;* the Arms of Thomas Lord Roos, created in 1525 Earl of Rutland, which were originally, *or*, two bars, *azure*, a chief *gules*, were thus altered: *or*, two bars, *azure*, a chief quarterly, first and fourth, two fleur-de-lys of France, second and third, a lion of England; and the Arms of John Churchill, Baron of Eymouth in Scotland, (*sable*, a lion rampant, *argent*,) were augmented by James II. with a canton *argent*, charged with a cross of St. George.

Henry VIII. was, in the highest degree, lavish of Heraldic distinctions. On Ann Boleyn he conferred the Arms of the Earls of Lancaster, of Angoulême, and Guienne, which she quartered with those of the alliances of her own family; but her family coat itself was dropped. To Jane Seymour he gave a coat of augmentation, *or*, on a pile, *gules*, between six fleur-de-lys, *azure*, three lions of England, which is quartered by the Seymours, Dukes of Somerset, to the present day. To Katharine Howard he assigned two whole coats, to be quartered with her own, *viz.* I. *azure*, three fleur-de-lys, in pale, *or*, on two flanches *ermine*, as many roses *gules;* and II. *azure*, two lions passant gardant, between four demi-fleur-de-lys, *or*. Lastly, to Katharine Parr he granted the following coat, to be quartered with her proper one: *argent*, on a pile, between six roses, *gules*, three others of the field.

4. While we are on the subject of Marshalling, we may be expected to notice what Menestrier calls *sottises Anglaises; abatements*, or symbols of disgrace introduced into Arms. In this respect we fear we are too open to the sarcastic Frenchman's assaults. Abatements, of course, are never used, except in a case which we shall presently mention; and in this, if they are follies, they are shared by our continental neighbours.

Abatements must always be tawny or murry, except only bastons. As it would be impossible or invidious to present the reader with *real* coats containing these abatements, we must give them separately.

Fig. 195 is a *delf*, or quadrant spot. If this bearing be repeated in the escutcheon, or be of metal, or charged, it is not to be taken for an abatement. This is the sign of a revoked challenge.

Fig. 196 is an *escutcheon reversed.* It belongs to him who uncourteously treats a lady, or deserts his Sovereign's banner.

Marshalling.

Fig. 197 is a *point dexter parted*, and belongs to a boaster.

Fig. 198 is a *point in point;* the designation of one who behaves slothfully in the field.

Fig. 199 is a *point champain.* It belongs to one who kills a prisoner of war.

Fig. 200 is a *gore sinister.* It is given to effeminate persons.

Fig. 201 represents two *gussets*, dexter and sinister. Both are abatements; the former for voluptuousness, the latter for intoxication.

The *plain point*, assigned for lying, is exemplified in fig. 3, where it forms the lowest division of the escutcheon.

The baston, already noticed, is the abatement of a bastard, and the only abatement used.* It is, moreover, hereditary, and can only be removed by the King. A bastard may bear his mother's Arms without this abatement; but if he bear his father's, he must add it. The illegitimate descendants of some of our Kings have thought fit to incur this blemish for the sake of retaining the Royal Arms; an instance of which we have in the family of Fitzroy, Duke of Grafton, whose coat will be found in fig. 64. The baston must not be borne of metal, except by the descendants of Kings.

A traitor's coat is represented reversed, and is not blazoned by the *technical*, but *proper* names of the tinctures, except where such tinctures are themselves technical.

Ensigns.

5. Ensigns are either national or personal. The antiquity of the former has been already shown; and they still retain some peculiarities of ancient Heraldry. They are, for the most part, different altogether from the Arms of the Country which they represent; except what are called "Standards," which are usually the same. The ensigns of the Norman Monarchs appear to have been wholly different from the National bearing and from each other. *Argent*, a cross, *gules*, was, at an early period, borne in the English army, and considered hence the National banner. In nothing is the Heraldry of National ensigns more decidedly distinguished from that of National escutcheons, than in the particular that while ordinaries rarely enter the latter, they are as rarely absent from the former. This circumstance also draws a wide distinction between the ancient and modern Heraldry of ensigns; and we may observe, as another distinction of this department of modern Heraldry, that colour, as in the escutcheon, so in the banner, is an essential feature. Yet the rules which prescribe the different combinations of colours and metals in ordinary modern Heraldry, have no application in the theory of ensigns.

Standard.

Gonfanon.

The largest species of ensign is the Standard, commonly of a square form, but now somewhat oblong. It was generally used by Sovereign Princes, or by the Commanders of armies. The Gonfanon, as used anciently, did not, according to Dr. Meyrick, resemble the species of ensign commonly termed by that name in modern Heraldry, but "was fixed in a frame made to turn like

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* "All the bastardis of all cotarmuris shall bere a fesse, sum call hit a baston of oon of the iiii dignites of colouris, except the bastarde of the fixiales, and the bastarde of the brethyrne of the cheve blode: where theritaunce is deparded to evych brothir e like moch, theys bastardis shall add more bagy to his armys, or take away a bagy of armys."—*Book of St. Albans.*

a modern ship's vane, with two or three streamers or tails. The object of the Gonfanon was principally to render great people more conspicuous to their followers, and to terrify the horses of their adversaries; hence the Gonfanon became a mark of dignity." These Gonfanons appear to have differed little from the Pennon. We have given some representations of ensigns called by ancient writers Gonfanons and Pennons. Yet that there was *some* difference is evident from the language of Wace:

Pennon.

> *Li barons ourent gonfanons,*
> *Li chevaliers ourent penons.*

The difference was, perhaps, rather in the charge than the form. Indeed, the Gonfanon appears to have anciently sustained the office of the banner, to indicate the presence of some important person; while the Pennon was borne by every ordinary Knight, as well as by the more powerful feudal dignitaries.

A writer in the *Retrospective Review*, to whose observations this department of our Treatise is greatly indebted, observes, "When the English army was composed of tenants *in capite* of the Crown, with their followers, it appears that such tenants were entitled to lead them under a banner of their Arms; but the precise number of men so furnished, which conferred this privilege, has not been ascertained. Judging, however, from the *Siege of Karlaverock*, it would seem that early in the XIVth century there was a banner to every twenty-five or thirty men at arms."[*]

"When the tenant *in capite* was unable to attend in person from sickness, or from being otherwise engaged in the King's service, he nevertheless sent the quota of men at arms and archers, for which, by the tenure of his lands, he was engaged; and his banner was committed to the charge of a deputy of equal rank to his own. Thus at Karlaverock, the Bishop of Durham, being prevented from attending by some public duty which detained him in England, he sent one hundred and sixty of his men at arms with his banner, which, it is worthy of remark, was simply that of his paternal Arms, without any reference to those of his See; which tends also to prove that in the field he was considered merely as a temporal Baron."[†]

"The most curious fact on the subject which is established by the Poem is with respect to the banner of an Earl; for it is evident that it was considered to belong to the dignity rather than to the individual. Ralph de Monthermer, the Earl of Gloucester in right of his wife, Joan, daughter of King Edward I., and widow of Gilbert de Clare, Earl of Gloucester, by which title he was repeatedly summoned to Parliament, led his followers on that occasion under the banner of Clare, the Earl of Gloucester, whilst he was himself vested in a surcoat of his paternal Arms, which he also bore on his shield." "The fact is the more worthy of attention, because it corroborates the opinion that he possessed the dignities of Earl of Gloucester and Hereford solely in right of his wife; for on her death in 1307 he ceased to enjoy them, and they were assumed by Gilbert de Clare, her son by her first husband; Monthermer being summoned to the very next Parliament as a Baron only."[‡]

Banners.

Corporations and Fraternities, secular and religious, had also their respective Banners; which, on particular occasions, were paraded in the field.

The Banner was not only displayed on a staff, but was also appended to the trumpets of the owner. It was borne, too, by Heralds, when acting on the part of the Prince or Chief to whom it belonged.

Beside this Banner, a Knight might have what was called his Standard, which differed wholly from the species of flag now known by that name; since, while the modern Standard universally displays the Arms, the early one always bore the badge or cognizance. The Standard was somewhat longer than a Banner, but not so deep. Both Standard and Banner led 100 men.

The Pennon, like the Banner, contained armorial bearings; every Knight having the command of 100 men was allowed to bear one of these. We have already spoken of the manner of creating a Banneret.

Guidon.

The Guidon, or, as some write it, Guidhomme, was the ensign of an esquire or gentleman, and conducted 50 men. It bore no Arms, but simply the crest, cognizance, or Device.

Pennoncell.

The Pennoncell might be used by any individual. It bore the cognizance, or "avowry," *i. e.* the name of the tutelar saint of the bearer.

This interesting department of Heraldry has in this Country almost wholly fallen into decay. At the funeral of Lord Nelson great attention was paid to ensigns, as well as to every other branch of the study; but at that of the late Duke of York the utmost disregard of the subject prevailed.

We here conclude our summary of this curious and not unprofitable theory. Prejudices, founded on generous and noble sentiments, but now fast decaying before opinions, which, if less prejudiced, are less honourably grounded, have exalted, it must be allowed, the pursuits of Heraldry to a very exaggerated and unmerited dignity; but there are extremes in this as in all subjects, and the contempt which the elegant fabric of Heraldry is fated to experience at the hands of utilitarians, is equally discreditable to modern taste and to modern knowledge. Heraldry is, at least, a very beautiful structure; and, if material utility must be the standard of Good, Heraldry, even here, may advance her pretensions. For if the maintenance of a high spirit of honour, attachment to existing institutions, and the preservation of those gradations to which Society is indebted for all its symmetry and solidity, be objects of importance, Heraldry has valuably contributed to all. Heraldry, too, was chief handmaid of the ornamental Arts in dark and barbarous Ages: and whatever may be said of the pedantry of early Heralds, who crowded their Treatises with information wholly alien from their subject, yet this alone is good evidence that a Herald, as such, was expected to be a man of various erudition; inasmuch as his very Science led him to treat of objects almost universal. Heraldry, too, has been the means of determining genealogies and inheritances through very remote conclusions: its use in illustrating History, both as regards customs and facts, must be allowed to be considerable; and its study, therefore, can never be unworthy the Historian, the Biographer, and the man of Letters; while the Philosopher may well be required to tolerate what has proved in many instances of essential value to Society.

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[*] *Retrospective Review, Second Series, Oct.* 1827.

[†] *Ibid.*

[‡] *Ibid.*

NUMISMATICS.

Origin of the Art of Coinage.

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Prior to the invention of stamped money, commerce was carried on by the exchange of commodities, and the little metal employed probably consisted of pieces cut without regard to shape but regulated by weight; for all large, and even for small sums recourse was, consequently, had to scales, and, if we take into consideration the diversity of weights existing in Countries apart from each other, we shall readily perceive the inconvenience attending this original barter. On the earliest Grecian Coins a variety of types appear which are derived, as we shall shortly explain, from circumstances connected with the Country; it will not then be unreasonable to suppose that each City having adopted some particular emblem, affixed it to the pieces of metal there struck, at once designating the City to which they belonged, and indicating in a manner their value. This stamping of pieces of metal was, in fact, a public testimony that they were of the weight required, and might pass in traffic without trial by scales. It will be obvious, that it was sufficient to affix the stamp on one side only of the Coin, but a difficulty arose as to the means of effecting this; if the metal were laid on an even surface, the dye containing the device placed upon it, and the hammer resorted to, the pieces would in all probability be displaced during the operation, and the impression would thus be rendered imperfect. At the present day, the piece of metal, or *planchet* as it is termed, is placed within a steel collar corresponding with it in size; but this being a contrivance unknown to the Ancients, the method they adopted may be thus explained. Deep grooves, generally two in number, were cut out of the surface of one extremity of a bar of metal or a puncheon, by which means projections were formed and the planchet was then laid thereon; in this manner, after a single blow of a hammer, the metal would be partially secured and retained in its place until the operation of striking was completed. From the great relief given to the early Coins, the type could only be brought out by repeated blows, and their extreme thickness and globosity leads us to suspect they were, in the first instance, of a spherical form. The Coins produced after the manner we have just described, would bear on one of the sides the type of the City rudely executed, and on the other several deep indentations made by the fixed puncheon; these depressions most frequently partook of a quadrilateral form, and were four in number; hence after the lapse of a few years, when the Coins were characterised by a greater degree of neatness, the reverses represented a square divided into four equal parts. The lines, which at first were of considerable breadth, insensibly disappear, and about the year 500 B.C. but one slight depression of a square form remained occupying the field of the Coin; this compartment served for the introduction of a second symbol, and instances occur in which the former divisions are slightly indicated on the surface.

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I.

Fabric of
the most
ancient
Coins.

We have as yet noticed but one variety of indentations on the reverses; for although about 500 B.C. the indented square prevailed throughout Greece, numerous modifications were employed before the dye assumed this simple character. Instances occur of Coins in which the dye is circular, but divided like the preceding into four parts; others there are, also, in which the bounding figure is square, but the cavities are triangular, from the cross lines running diagonally.

The Coins of some Cities of Asia Minor present a singular variety; in these the surface on which the metal was placed had angular pieces cut out, not the deep grooves noticed above; as it is difficult to convey in words an idea of this modification, we have given a representation of the form of the end of the instrument by which, possibly, it was effected. The difference in the appearance of the Coin thus formed will be, that instead of the area being divided as before by bands, the separation is effected by an angle of each department being considerably depressed. The improvements resulting from this variety in the dye may be easily conceived; in the course of time it was found unnecessary to give so great a depth to the depressions, which therefore gradually became less apparent, and about the year 460 B.C., but four slight triangular indentations are seen, disposed like the sails of a windmill. There are a few Coins in which the triangular parts are given in relief, possibly suggested by the preceding variety, and admirably adapted for fixing the planchet during the operation of forming the type. The depressions were by no means limited to four, although that number is by far the most frequent; on the Persian Coins denominated *Darics* but one indentation appears, of an irregular form, and on ancient Coins ascribed to the city of Ephesus there are two; on early Coins of Dyrrachium and Corcyra three cavities may be seen, on those of Egina they are, with scarcely an exception, five in number, and in those of Sicily yet more numerous. Two varieties, more complicated, occur of Bœotia and Thebes; on a few Coins of these Cities the square is divided both by transverse and diagonal lines, thereby forming the triangular depressions before alluded to.

Plate II.
Fig. 10.
Coins of
Asia Minor
coeval with
the Lydian
Kingdom.
Fig. 11.

Fig. 12.

Plate I.
Fig. 1.

The first attempt at the introduction of types on both faces of the Coins, appears in the insertion of some small object in one of the compartments. On Coins of Egina a Dolphin is common; and in a few of Syracuse, the square divided into four parts may be recognised, and in the centre a circular cavity is reserved containing a head of Proserpine.

Fig. 2.

Such are the combinations in early Coinage which possess chief interest, and these are as many as our limits will permit us to detail. There are a few Cities on the Coins of which the progressive stages of the Art may be traced, as is the case with those of Chios; some Cities also retained to themselves a peculiar modification; thus in the colonies constituting Magna Græcia, a singular method was practised, but one equally effectual for securing the planchet; the Coins of Metapontum, Tarentum, Crotona, Sybaris, and Posidonia, are hollowed on the reverse with the obverse in relief with the same object: these Coins, termed *incused*, we may presume to have been struck at the period during which the simple square dye prevailed in Græcia Propria. One advantage gained by this method was, that these

Coins of
Magna
Græcia.

Coins required a smaller quantity of metal; the pieces exceed in their diameter the ordinary dimensions of Greek Coins, but are extremely thin.

Plate I. Fig. 5.

Coins of Macedonia.

Fig. 4.

The Cities of Maronea, Abdera, Acanthus, Amphipolis, and Ænos, situated on the coasts of Macedon and Thrace, near to their junction, have commonly on their Coins a double square, a peculiarity which being found to exist on Coins of the Macedonian King, Alexander I., determines their age. (500 B. C.) On the reverses of these Coins the divided square appears, considerably reduced in size, around it the name of the City is inscribed, and there is a second square beyond. The divisions of the inner square were afterwards omitted when some device was introduced, and in a short time the inner square was altogether dispensed with.

Having in the preceding remarks shown the possibility of effecting a chronological arrangement of these curious Coins by a careful examination of the indented marks, it may be proper to state, that the interpretation we have assigned to them is not altogether in accordance with the opinions hitherto received. In hazarding these conjectures we would by no means insist that the various figures certainly originated in the manner we have described, but we think the supposition consistent throughout, and neither forced nor improbable.

PART I.—Ancient Coins.

- Grecian ..
  - Civic.
  - Monarchic.
- Roman ..
  - Consular .
    - Roman *Asses.*
    - Coins of the Families.
  - Imperial .
    - Roman.
    - Grecian.
      - Provinces.
      - Colonies & *Municipia.*
  - Medallions
    - Roman.
    - Grecian.
- Barbarian.
  - European.
  - Asiatic.
  - African.

Sect. I.—Grecian Coins.

I. Grecian Civic Coins.

The Coins of the Greek Cities may be subdivided into those 1. of Græcia Propria, and the Islands; 2. of the Greek Colonies; and 3. of the Greek Cities in Asia. The first two divisions embrace Coins from the invention of the Art of striking them until the subjugation of the Country by the Romans. The third division is of minor importance, comprehending the Coins of Cities founded by Alexander the Great while prosecuting his conquests in the East. This class terminates with the Augustan Age, and includes many Cities of Asia Minor, Arabia, Palestine, Syria, and Mesopotamia.

Era of Grecian Civic Coins.

No chronological arrangement of the early Coinage of the Grecian States can at present be effected, but we are, nevertheless, induced to offer some hints for the consideration of the student on their probable era; viewing them in connection with the Coins of the ancient Kingdoms of Lydia and Persia. The subject has indeed seldom been more than imperfectly touched upon; and we conceive much valuable information connected with the chronology of Ancient Greece, the progress of the Art of Sculpture, and comparative wealth of the several States, might be obtained, if this inquiry were more fully pursued. We shall confine our remarks to a few Coins on which there remain grounds for reasonable conjecture as to their era; such are those of Egina, of Macedonia, and of Græcia Magna, but we have first to notice the Coinage of the Asiatic Countries.

Of Grecian Civic Coins.

Lydia.

Plate II. Fig. 10.

The Lydians occupied a portion of Asia Minor, lying between the rivers Thermus and Menander, and are the nation recorded to have first stamped the metal used in commerce.* Upon reviewing the annals of the Lydian Kingdom, we shall find their History, at the commencement of the VIIIth century B. C., involved in obscurity, and intermixed with fable; at that period also the surrounding nations enjoyed independence. Upon examining the Coins ascribed to this Country, we will venture to say that the rudest among them cannot claim a higher antiquity than many of acknowledged Grecian workmanship, which we shall show in the sequel to have been struck about 600 B. C. Under Crœsus, 560 B. C., Lydia was incorporated with the Persian Empire, and as we must assign the year 700 B. C. as the earliest date for the practice of the Art of Coinage, we may consider the Lydian Coins as having been struck during this interval. It may be remembered that throughout the Poems of Homer, who flourished, according to Newton, 870 B. C., no passage is found from which we can infer the existence of stamped money, an omission which could scarcely have occurred if Coins had been in his days a medium of commerce.

Persia.

Fig. 12.

The earliest of the Persian Coins in existence are the pieces denominated *Darics*, and commonly referred to Darius I., who ascended the throne 521 B. C. Upon a careful inspection of them, they will be found scarcely reconcilable with this date, being of extreme rudeness, whereas the Greeks of Asia Minor had, at the period in question, arrived at some proficiency in the Art. We may then conjecture that they were issued by order of Darius, a King of the Medes, who, upon a partial conquest of Lydia, 544 B. C., caused the money of that Country to be recoined for his own use.†

Græcia Propria.

Plate I. Fig. 1.

For the epoch of the institution of Coinage in Græcia Propria, antiquaries usually adduce a passage in the Arundelian Marbles, relating that Phidon, a Prince of the Argives, established a Mint in the Island of Egina, 869 B. C. The Coins struck by him bear the marks of high antiquity, and as they are found to this day in great numbers, must have circulated extensively. The date assigned for these Coins will be perceived to be quite at variance with the generally received opinion that the Lydian Coinage is the most ancient. To free ourselves from this embarrassment we may observe, that a Prince, also bearing the name of Phidon, is reported to have flourished nearly three centuries later than the former, while the events recorded of their lives perfectly coincide; a circumstance so improbable, that Sir Isaac Newton without hesitation rejects the first name as fictitious, and fixes the date of Phidon at 584 B. C. We heartily concur in the opinion entertained by this great Philosopher, and we conceive that we shall not greatly err, if we place the earliest Coins of Egina as struck about 600 B. C. This conclusion will guide us in ascertaining the era of many Coins of the neighbouring Cities and Islands, as Thebes, Melos, &c.

Macedonia.

Coins of great antiquity are found of many Cities of Macedon and Thrace, bordering on the coast of the Egean Sea. A knowledge of the circumstances which gave rise to a Coinage in this distant region, will acquaint us also with the period of their fabrication. The founda-

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* Herodotus, i. 94.

† Newton, *Chronology, Babylonians and Medes.*

tion of the Kingdom of Macedon is commonly ascribed by Chronologers to Caranaus, a relative of Phidon; a circumstance which will justify the supposition of a Mint having been established in that Country, in imitation of the one in Egina: this conjecture receives additional strength, if we might not say confirmation, from the weights used in both Countries being found to be the same.

agna ræcia.

We have lastly to notice, the introduction of Coinage in Magna Græcia; an inquiry attended with more difficulty than the preceding, from the various nations who inhabited its coast, and the several periods of their migration. When treating of the Monarchic Coinage we shall have occasion to speak of the Coins of the early Princes of Syracuse, and as the subject will throw some light upon the Civic Coinage of the surrounding Country, the reader is referred to that section. It will answer our present purpose to observe, that but few Sicilian Coins appear to have been struck until 500 B. C.

ymbols on recian oins.

Our next inquiry relates to the symbols of the Greek Coinage, and the causes which gave rise to a few of the most interesting. They will fall under three heads; *viz.*

I. Peculiar symbols adopted by the early Greek Cities.

II. The Deities and their attributes.

III. Symbols used in common by Greek Cities.

I. The greater number of the symbols included in the 1st division fell into disuse about 400 B. C., and after the lapse of about a century, the practice of introducing the heads of the Deities became general throughout Greece. The symbols included under the first class take their rise from local traditions and fabulous History, from the productions of the climate, and from distinguished characters and edifices of celebrity.

mbols rived m local ditions d fabu- sHistory.

Argos.—Under the reign of Gelanor, an early Prince of Argos, Danaus, an Egyptian, sought to deprive him of the Kingdom. A day was appointed for a public assembly to decide on their respective claims, on the eve of which a bull and a wolf, from the neighbouring mountains, fought under the walls of the City: the Argives assimilated the bull to Gelanor, and the wolf to Danaus; and the wolf proving victorious, the crown was awarded to the Egyptian Prince. In commemoration of this event, the Argives stamped on their Coins the device of the forepart of a wolf.

Byzantium.—It is related of Philip II. of Macedon, that meditating an attack on this City on a cloudy night, the moon suddenly shone forth, and discovered the approach of his army in sufficient time to enable the inhabitants to repulse him: the moon was ever after venerated as the preserver of Byzantium, and the event recorded by the symbol of a crescent. The Turks when they took possession of Constantinople in the XVth century, perceiving the type in many parts of the City, and ignorantly suspicious of lurking magic, thought to propitiate its unknown powers by the adoption of the symbol.*

Clazomene.—A tradition long prevailed that a winged boar appeared in the territory, and laid waste a great extent of country;† the inhabitants affixed, in consequence of this circumstance, a representation of the monster on their Coins.

Corinth.—According to fabulous History, the hero Bellerophon discovered the horse Pegasus, prior to his engaging, the Chimera by a fountain situated at the foot of the citadel of Corinth; hence that animal forms the symbol on their Coins.

Symbols on Grecian Coins.

Ephesus.—Philostratus relates that the Athenians, about to plant a colony on the coast of Asia Minor, were directed in their course to the spot on which this City was afterwards founded, by a swarm of bees, which preceded the vessel. Hence we have the origin of the symbol of a bee on Ephesian Coins.

Gortyna.—The symbol is that of Europa, recording the fable of Jupiter having conducted the daughter of the Phœnician King Agenor across the sea to the Island of Crete.

Heracleia.—There were not less than 100 Cities of this name, all of them founded in honour of Hercules. The symbols on the remaining Coins of a few of these Cities represent Hercules strangling the Nemæan Lion.

Stymphalus is memorable for being the spot at which Hercules destroyed the voracious birds *Stymphalides*, which fed upon human flesh. The hero is depicted in the act of discharging an arrow: the objects at which he aims are necessarily excluded.

Ilium.—The fate of ancient Troy is recorded on Coins of this City by the figure of Æneas bearing his father Anchises on his shoulders, and attended by the young Ascanius.

Symbols derived from the productions of the climate.

Lesbos, *Chios*, *Lampsacus*, and *Thasos* were famed for their excellent wines, and, in consequence, among the devices, heads of Bacchus and Silenus frequently appear; also ivy-leaves, grapes, amphoræ, a variety of drinking vessels, and the panther, an animal consecrated to Bacchus, may be seen.

Cyrene.—The symbol is the plant *silphium*, peculiar to the Country.

Metapontum and *Leontinum.*—The country surrounding these Cities was remarkable for its great fertility, so much so that, in Leontinum, corn was reported to grow wild. The symbol adopted by the former City was an ear of barley; by the latter, a lion's head, surrounded by grains of barley.

The devices on the Coins of many Cities lead to the origin of their names, these being derived from their productions, their fancied resemblance to some familiar object, &c. The most remarkable of this kind are the following.

Agrigentum, called by the Greeks *Agragas*, from *κράγων*, a crab. This animal is the type of the City, which was named after the river near which it was founded.

Clides, from Κλεὶς κλειδὸς, a key, the device adopted from the Island being assimilated in form to that object.

Cardia, from Καρδία, a heart, the symbol which may sometimes be seen on the Coins of that City.

Melos, from Μῆλον, a melon, a common symbol on the early Coins of Melos, either from the fruit abounding in the Island, or its fancied resemblance to it in form. The meaning of this word is doubtful, the common construction given being that of apple; but the fruit represented on the Coin does not perfectly resemble either that or the melon.

Rhodes, from Ῥόδον, a rose; it may, perhaps, also be translated the flowers of the pomegranate, the invariable type of the city.

Selinus, from Σέλινον, parsley. A leaf of this herb is the common type of the City, which received its name from a neighbouring stream, so called from the plant being found in large quantities on its banks.

Side, (Pamphylia,) from Σίδη, a pomegranate, the type of the City.

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* *Historia Byzantina*, i. 7.

† Ælian. *De Naturâ Animalium*, xii. 38.

Distinguished characters and edifices of celebrity.

Of the Cities which contend for the honour of giving birth to Homer, Smyrna and Chios have the fairest claim: on the Coins of the former the bust of the Poet forms a common device; on those of the latter he is represented at full length with his Poems in his hands. Sappho appears on Coins of her native City Mytilene in Lesbos, Lycurgus on Coins of Lacedæmon, and Ajax, the son of Oileus, forms the constant type on those of Opus, the Capital of part of Locris, and birth-place of the hero.

Crete was famed for its labyrinth, situated near the ancient Capital Cnossus, which constitutes the chief symbol on the Coins of the City. For the City of Rhodes, a radiated head of Apollo affords the type of the obverse, which there are some grounds for believing to have been copied from the celebrated Colossus. The splendid City of Ephesus was memorable through successive Ages for the Temple erected to Diana, that Goddess being worshipped there with peculiar honours; representations of the porch of this Temple are given on Coins struck during the Imperial Ages of Rome: they differ slightly from each other, as the edifice was frequently rebuilt. On Imperial Coins of the Island of Cnidus, the celebrated statue of Venus by Praxiteles is represented.

Symbols of Deities.

II. The IId division of symbols on Grecian Coins consists of the Deities and their attributes; these would naturally be suggested as the devices most appropriate upon the discontinuance of the indented square, and while the obverse sufficed to contain the type of the City. The chief Greek Deities appearing on the Civic Coins are the following.

Jupiter. The attributes *an Eagle* and *Thunderbolt.* On Coins of Epirus and Thessaly, the head of the Deity is crowned with oak-leaves: he had a celebrated Temple at Dodona, in the former Country, near which City was a grove of oaks, the leaves whereof were said to be endowed with the gift of prophecy.

Crete was the birth-place of Jupiter, his head is therefore common on Coins of the Cities in that Island. On Coins of Cyrene he is represented in the character of Jupiter Ammon, as on those of the Egyptian Princes.

Juno.—Peacock. The head of Juno is common to Grecian Coins; the Peacock may be seen on a few Coins of the Island of Samos, famed for its Temple erected to that Goddess, a representation of which is given on Coins struck in the Imperial Ages.

Plate I. Fig. 7.

Pallas.—Owl and *Pegasus.* The head appearing on the obverse of the silver Coins of Athens (the City consecrated to the Goddess) is invariably that of Pallas, and is conjectured to be copied from the celebrated statue of Phidias. On Coins of Ilium, the Trojan Pallas forms a common type.

Neptune.—Trident, Dolphin, and *Seahorse.* The City of Posidonia, (Ποσειδῶν, Neptune,) in the Country of Lucania, was founded in honour of that Deity; the coins are *incused,* (a character we have noticed as peculiar to the early Coins of Magna Græcia,) and bear for their type, without exception, a figure of the God.* Trœzene, a City of Argos, and the birth-place of the hero Theseus, acquired celebrity from its Temple erected to Neptune; a Trident was, in consequence, affixed on the Coins.

Apollo.—Tripod and *Lyre.* We have spoken of a head of Apollo on the Coins of Rhodes, supposed to be taken from the Colossus. The Cities of Chalcis in Eubœa, Mytilene, and Colophon, bear the type of a lyre on the reverses of their Coins; they were all famed for the worship of Apollo.

Symbols on Grecian Coins.

Venus.—A Dove. Cnidus, a City famed for its Temple to Venus, bears on its Coins a head of the Goddess. The symbol on the Coins of the Cities of Sicyon, and the Islands Seriphus and Siphnos is a dove, possibly bearing an allusion to the worship paid to Venus.

Diana.—A Hind. This animal is common on Coins of Ephesus, and on those of the City of Perga, in Pamphylia, memorable like the former for its Temple to Diana; a figure of the Goddess is given. Syracuse and Massilia had also Temples to Diana, and her effigy is of frequent occurrence on their Coins.

Ceres and *Proserpine.—Ears of Barley, Torches, &c.* The City of Eleusis, famed for its mysteries, offers on its Coins a representation of Ceres drawn in a car by serpents. Ears of barley are introduced on Coins of all the Cities of importance in the Island of Sicily, where the above Deities formed the chief objects of worship.

Hercules.—A Lion, Club, Bow and *Arrows.* We have already mentioned the Cities of Heracleia as presenting the device of Hercules strangling the Nemæan lion. Thebes was the birth-place of the hero, his head was in consequence sometimes introduced on the Coins of that City; he is represented also, on a few of them, strangling the serpents. Hercules was one of the chief Deities of the Tyrians, and his head forms a constant device on their Coins; lastly, on Coins of the Island of Thasos he appears shooting with his arrows: that Island was noted for a Temple to the Demigod.*

Bacchus.—Amphoræ, Grapes, Vine-leaves. Thebes gave birth to Bacchus, as well as to Hercules; hence when heads are given on the Coins (which does not frequently occur) they are of one or other of these Deities. *Amphoræ* are the most common devices on Bœotian and Theban Coins.

Pan.—A Goat. The animal may be seen on Coins of Macedonia, and on those of Arcadia; the God appears reclining on Mount Olympus.

Mercury.—An Antelope. This is the sole device on Coins of the City of Ænos, in Thrace.

Symbols used in common.

III. The IIId and last division includes a variety of symbols appearing in common on Coins which have not appropriated to themselves any peculiar device. The greater number of them are emblematical of warfare, (the symbols which would naturally suggest themselves to nations inured from infancy to the use of arms,) and may be referred to the Northern and less Civilized States of Greece.

Plate I. Fig. 2.

A Horse is the symbol common to Macedonia and the chief Cities of Thessaly, *viz.* Larissa, Pharsalus, and Tricca; the inhabitants of those regions acquired celebrity for their skill in the training and management of this animal, whereof the habitual use probably gave rise to the Fable of the Centaurs.

Fig. 3.

A Shield of an oval form is the type of Bœotia, appearing with scarcely an exception on Coins of the Cities Thebes, Platæa, Tanagra, and Thespis. On Coins of a few Macedonian Kings also we meet with a circular shield, variously ornamented. In addition to these devices we may notice frequent representations of *Warriors, Helmets, Clubs, Spears,* and other implements of battle. Lastly, we have the Cities situated on the sea-coast, and distinguished by their commerce, such as those of Asia

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* A Coin of this City, delineated on an enlarged scale, may be seen in plate ii. fig. 4, illustrating the Essay on SCULPTURE.

* Herodotus, ii. 44.

Minor, Phœnicia, and Græcia Magna. The symbols adopted by these consist chiefly of *Vessels, Prows, Rudders, Tridents;* a variety of fish, as the *Dolphin, Crab,* &c.; and in a few instances *Shells.*

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The conquests of Alexander and his Government in Asia, gave rise to the establishment of numerous Grecian Cities throughout Asia Minor, Syria, and Palestine. His General, Seleucus, founded no fewer than 134 Towns, of which Antiochia, Seleucia, Apamea, and Laodicea were the chief. The devices commonly affixed on the Coins of these places were the heads of the Deities and their attributes. The Coins of this division are, as we might conjecture, infinitely more numerous than the preceding, but from the sameness of the devices they afford little interest.

egends on
recian
oins.

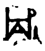
We shall conclude the subject of Civic Coins by some account of the characters constituting the Legend. The Inscriptions of the greatest simplicity were those of the early Republics; for as Kingdoms became powerful, depraved by luxury, and verging to decay, so their Legends became diffuse, being filled with expressions of adulation calculated to nurse the ambition and flatter the vanity of Princes. While Coinage was limited to a few Grecian States, and each appropriated to itself a device, it will be obvious that it was superfluous to insert the name of the City, and hence the greater number are destitute of characters, if we omit the occasional insertion of the initial letters in the compartments formed on the reverses. But when Coining became general throughout Greece, and symbols of the Deities were substituted and promiscuously employed, it was then found requisite to inscribe the names either at length or in an abridged form.*

ate I.
g. 7.
g. 3.
g. 2.

On Coins of Abydos, in Mysia, the single initial letter first occurs; we have afterwards AB, also ABY, and sometimes the entire name, ΑΒΥΔΙΩΝ, in the genitive case, money being understood. On Athenian Coins ΑΘΕ is commonly inscribed on the early Coins, and afterwards ΑΘΗΝΑΙΩΝ. Thebes is expressed by ΘΕ, Syracuse by ΣΥΡΑ, and so on. It may be remarked also that on the earliest Coins, particularly those of Græcia Magna, the characters are frequently placed in retrograde order.

nograms

In order that these characters should occupy less room on the Coin, and not interfere with the device, *monograms* were introduced; these are figures comprising a portion of the name, in which the characters are so interlaced that a limb of one applies to many. By this ingenious method an entire name might be brought within a space of little more extent than that which was previously occupied by an individual character. The following will serve as illustrations:

Achaia. Panormus.  Heracleia. Leontinum.

Grecian
archic
s.

The Civic Coins about the Age of Alexander the Great have been stated to bear for their devices, heads of the chief Deities, and the attributes peculiar to them. The Coins which now demand attention differ from the Civic in presenting the portraits of Princes (there are, however, many exceptions) in lieu of the heads of Deities; the reverses mainly consist of figures of Deities who formed the chief object of worship in the particular City in which the Coin was struck, and were, probably, copied from statues erected to their honour.

The period of History which these Coins serve to elucidate is that which has received the denomination of the Grecian Empire, commencing with Alexander the Great, and closing with the extinction of the dynasty of the Lagidæ, in the Augustan Age. Independently of the Kingdoms included in this Empire, a few Coins exist of the Kings of Epirus, also a series of the Syracusan Princes.

Divisions of
Monarchic
Coins.

The Coins of the Grecian Empire may be divided into those of the four Kingdoms established upon the final division of Alexander's dominions, *viz.* the Kingdoms of Macedon, Thrace and the Western parts of Asia Minor, Syria, and Egypt; also the portions of these which were subsequently formed into distinct dynasties. Under this second division we have the Countries of Armenia, (divided into the Greater and the Lesser,) Parthia, Bactriana, Judæa, Commagene, and Osroene, or Edessa, in Mesopotamia.

Macedon.—The Coins of this Kingdom claim our first attention; for omitting those which bear the head of Gelo, first King of Syracuse, (referred by some antiquaries to the reign of that Prince,) they precede by upwards of a century the Coins of any other race of Grecian Princes. As this series is of considerable extent, and slightly varied in its character according to the periods in which the Coins were struck, we may divide it into three classes: the first of these commences 500 B. C. with Alexander I. and closes with Amyntas, the father of Philip II.; under the second division will fall the Coins of Philip II. and Alexander the Great; and the third includes those of the remaining Princes, until the final subjection of the Country to the Romans.

Plate I.
Fig. 4.

I. This division is chiefly interesting from including many pieces bearing the rude indentations peculiar to the early Coinage. As these have already been described in treating of the Civic Coins, further detail is needless. The Coins of Alexander I. are in silver, and of great rarity, as are also those of his immediate successors; the most common type on the early, and indeed late Coins of the series is a Horse with or without a rider, and upon the introduction of symbols on both sides of the Coins, a head of the young Hercules clothed in the lion's skin. Hercules was a Deity highly honoured in Macedonia, as the inhabitants deduced their descent from him.

Coins of
Philip II.
and Alexander the
Great.

Fig. 9.

Fig. 8.

II. We have just observed that the Coins of the first class were indicative of the infancy of the Art among the Greeks, and it is remarkable that it attained to considerable excellence in little more than a century from the discontinuance of the indented square. Many Coins of this division are indeed of the best style of Grecian workmanship, and as the Princes to whom they refer are among the most distinguished in History, they merit some attention. Numerous as are these Coins, it is remarkable that they offer but little variety in their devices, it is also doubtful if any Coins of Philip were struck in copper; the reverses of those in gold and silver bear symbols commemorative of his victories in the Olympic Games; the head appearing on his silver Coins is invariably that of Jupiter, a Deity whose worship was very ancient in Macedon. The gold Coins of Alexander the Great bear a head of Pallas, (a favourite Deity of that Prince,) also figures of Victory, in allusion to his extensive conquests. On the silver Coins a figure of Jupiter is represented, a symbol which afterwards became common to Coins of the Grecian Empire. The God appears seated, bearing in his right hand an eagle or a figure of Victory, and in his left a sceptre; the figure was probably

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* For some of the forms in which the names appear on ancient Coins, see Abbreviations, in our *Miscellaneous Division.*

copied from the renowned Statue by Phidias, at Olympia. On the obverse of the Coins with this device, we have a head of the young Hercules clothed in the lion's skin; these symbols were affixed to Alexander's Coins in consequence of his tracing his descent from the last-mentioned Deity, and from his earnest desire to be regarded as the son of Jupiter. The bronze Coins of Alexander are unimportant, as they are of inferior execution, and the symbol consists but of a repetition of the devices just named. It may be remarked that none of the Coins struck during the life-time of that Prince are known to preserve his portrait, although the practice of introducing the heads of Princes was not uncommon in his Age. Visconti has with much pains endeavoured to prove that his features are preserved on a few Coins under the character of the young Hercules, but the result of his observations is unsatisfactory.*

III. The Coins of Philip V. abound in Cabinets; they are greatly diversified in their symbols, and many in silver are of very good workmanship.

Copper Coins of the Greek Kings.

The copper Coins of the Greek Empire are seldom deserving of much attention; inferior in their execution to those in silver, they offer devices but slightly differing from the Civic Coins, *viz.* the heads of Deities and their attributes; the greater number of the Coins after Alexander the Great are of this kind, and consequently of little esteem.

Thrace and part of Asia Minor formerly constituted the chief possessions of Lysimachus, in the division of Alexander's dominions; the Eastern portion, however, of the latter Country fell to the lot of Seleucus. Soon after the death of Lysimachus, Thrace was overrun by the Gauls, and Asia Minor was formed into several independent Kingdoms.

Thrace.—The silver Coins of Lysimachus are very numerous, and bear the portrait of the King; the horn behind the ear is symbolical of power and strength, and was assumed by a few of the Generals of Alexander, the supposed son of Jupiter Ammon. The gold Coins of this Prince resemble the silver; the copper are unimportant.

At the fall of the Greek Empire, the Gallic Chiefs, who held possession of the Country, struck Coins; they are all of copper, indifferently executed; and in lieu of the ordinary symbols on the reverses, they bear the portraits of the Roman Emperors in token of allegiance. This series extends to the reign of Caligula.

Asia Minor.—*Caria* is the most ancient Kingdom in this territory of which a series of Monarchic Coins is preserved; on the obverse are heads of Apollo, resembling those on the Coins of Rhodes; the type of the reverse is a figure of Jupiter *Labradeus*, (so named from his bearing an hatchet:†) Jupiter was the chief Deity of the Carians, and had a splendid Temple at Halicarnassus, the ancient Capital and Royal seat. This series extends to the Age of Alexander.

Mysia, or *Pergamus.*—Philetærus, the Prince who founded this dynasty, appears, from the Coins, to have had his name used in common by the race, a practice by no means unfrequent in the East: the portraits on the numerous Coins usually ascribed to him, exhibit too great a diversity of character to authorize a supposition that they were intended for the same individual. On the reverse, a figure of Pallas is represented, seated, and holding in her right hand a laurel crown; this type alludes to the solemn Games instituted in honour of that Goddess, at Pergamus, by Philetærus, and observed by the succeeding Princes. The copper Coins of this series are few in number, and little worthy of notice.

Bithynia.—The silver Coins of this race of Princes represent their portraits boldly executed, and on their reverses a figure of Jupiter. He had a Temple at Nicæa, the Capital, and is represented with his right hand extended, bearing a laurel crown, the reward of the victors in the Games instituted in his honour.

Cappadocia.—A very complete series of the Coins of the late Princes of this Country is preserved, inscribed with the years of their reigns, as indeed are many Coins of the Bithynian Kings. Pallas bearing a figure of Victory is the type of the reverse.

Pontus.—But a few Coins remain of the Princes of this Country; indeed, until Mithridates the Great, its History is little known. The series is not characterised by any peculiar device; the Coins of Mithridates are numerous, and possess great beauty; the symbol is commonly a Hind, encircled by an ivy wreath; and occasionally Pegasus, a type of the City Amisus, is substituted.

Bosphorus.—In connection with Pontus we may notice this remote region, governed from an early period by Kings whose names alone remain. The utility of ancient Coins to the Historian is in few instances more remarkably shown than in the Coins of this Kingdom, as those of a race of Princes scarcely mentioned in History, are preserved entire for upwards of three centuries; and from the dates being given with each, we are enabled to ascertain the precise year of the accession of many of them. Several of these Coins are composed of the mixed metals denominated *electrum* and *potin;* the former compounded of gold and silver, and the latter, silver debased with copper. The execution of these Coins is very indifferent; indeed those of the last five reigns scarcely preserve the form of the human countenance: the series extends from Augustus down to Constantine the Great, and on the reverses the heads of the Roman Emperors, to whom they acknowledged allegiance, commonly appear.

Egypt.—If we omit the Coins of the Seleucidæ, those of the descendants of Alexander's General, Ptolemy, who fixed themselves at Alexandria, form the most beautiful monarchic series extant. They acquire additional interest from preserving portraits of the Queens; many are unrivalled in execution, and the gold Coins, both for size and number, exceed those of any other Kingdom. The devices are but of two kinds, an Eagle on a thunderbolt and a Cornucopia; the introduction of the first symbol is conceived to have originated either from Ptolemy I. deducing his descent from Jupiter, or from his life having been preserved by an eagle, when exposed in his infancy in the woods: the cornucopia, on the Coins of the Queens, was probably emblematical of their deification, the symbol being given to the propitious Deities. The copper Coins of the Egyptian Kings are destitute of portraits, the head of Jupiter Ammon forming the sole type of the obverse: on the silver Coins the year of the Prince's reign is frequently inscribed, prefixed by a character resembling the English letter L. In this series are a few gold Coins highly interesting from the portraits they transmit, and which give them the character of Medals; the pieces we

Plate I Fig. 6.

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* *Iconographie Grecque, Rois de Macédoine.*

† Plutarch, *Quæst. Græcæ.*

allude to represent on one of the sides the portraits of Ptolemy I. and Berenice, and on the other those of the IId Ptolemy (Philadelphus) and Arsinoe.

Syria.—A few gold Coins exist of the early Kings of Syria, but all are of extreme rarity; the series in silver possesses great beauty, and is preserved entire of nearly all the Kings, (twenty-six in number:) from the diversity of character these exhibit, and from the resemblances which may be traced in branches of the same family, there is every reason to believe that the likenesses are correct. On the reverses of the above Coins we meet with figures of the Deities who formed the chief objects of worship: the first in importance is Apollo; he is represented on the *Cortina*, a seat of a conical form, placed over the spot whence the gale of inspiration was conceived to arise: this device appears on the Coins of Seleucus I., the reputed son of the God. With Antiochus IV. we have the type of Jupiter, closely resembling the figure on Coins of Alexander the Great; the adoption of this symbol arose from a celebrated Temple, erected to Jupiter in Antioch, having been embellished by this Prince, who also caused a Statue of the God, copied from that at Olympia, to be placed therein. On Coins of succeeding Princes, Pallas and other Deities appear.

Armenia.—The few Coins which remain of this extensive region are indicative of the rude state of the Art; and the Princes to whom they refer are scarcely known in History.

Parthia.—The Coins of the Parthian Kings differ in their general appearance from all of the preceding, yet they possess little variety among themselves; the series extends throughout nearly five centuries, and from the changes they underwent during this period, we may consider them as consisting of three kinds. I. This division includes the reigns of twelve Princes, and extends to about fifty years before the Christian Era; the Coins are small in size, and have for the type of the reverse the King seated, holding in his hand a bow. The portraits, which manifest a progressive improvement in the execution of the Coins, are rendered interesting from the pains bestowed in the delineation of costume. The figure on the reverse is encompassed by a Legend of some length, as in addition to the name Arsaces, common to the race, a surname is occasionally introduced, serving to distinguish the Princes, the epithet ΦΙΛΕΛΛΗΝ, or friend to the Greeks, and the pompous title "King of Kings." II. The greater number of these are of a large size and of superior workmanship; some variety is also given to the device of the reverse, in which a female appears presenting a crown to the Monarch. III. The third class includes the Coins of the last few reigns, which are only remarkable for their extreme barbarism. This series is in silver, with the exception of those forming the last division, where copper is mixed in such large proportion with the silver, as to constitute the metal called by the French *potin;* dates appear on late Coins of this dynasty, (commencing from the era of the Seleucidæ 312 B. C.,) and they furnish the only means of appropriating with certainty the Coins of many of the Kings.

te I.
g. 11.

Bactriana.—The discovery of Coins of a few Princes who reigned over this distant Country, the most remote of Alexander's conquests, has enabled antiquaries to ascertain, in some degree, the order of succession of the Kings; and little as we are acquainted with their History, there is much reason to believe that the Kingdom at one period had attained great power. The Coins are unquestionably the work of Greek artists.

Judæa.—The earliest known Coins of this Country were struck during the dominion of the Maccabees, and the greater number may be referred to Simon Maccabeus, his name being inscribed thereon in Samaritan characters. The symbols of most frequent occurrence are Vine-leaves and Palm-branches, and to the Coins of Princes of a later date, Cornucopiæ. Coins remain of the three Herods and two Agrippas; they are of copper, and bear dates like the Egyptian.

Commagene.—These Coins are of copper, and consist, with scarcely an exception, of those of Antiochus IV., his Queen, and their sons. The sign Capricornus is a common type, being that under which the Emperor Augustus was born; this symbol, as will be hereafter shown, is common to the Coins of that Emperor, and was probably introduced on this occasion from Antiochus IV. having acquired the territory through his influence.

Edessa.—The Coins of the obscure race of Princes who reigned over a part of Mesopotamia, of which Edessa was the Capital, are, like those of the preceding Countries, in copper, and of rude workmanship. The order in the succession of the Princes can be ascertained only from the heads of the Roman Emperors occupying their reverses, the name Abgarus being common to the Kings, and, with but one exception, the only one introduced in the Legend.

Syracuse and *Epirus.*—The Coins of these Kingdoms, which we have delayed noticing hitherto, as they do not fall under the Greek Empire, are here taken in connection, because many of the latter Country, to all appearance, are the fabrication of Sicilian artists. The Coins of the Syracusan Kings differ but little in their general character from those of the other Grecian States; they are greatly diversified, and for beauty of execution rival any extant: the symbol of most frequent occurrence is that of a Victory guiding a chariot, a device commemorative of the solemn Games instituted in honour of Ceres and Proserpine. Much contrariety of opinion prevails respecting the era of the supposed Coins of Gelo, the first King of Syracuse: (elected 494 B. C.) the reader will remember that we stated the invention of the Art of Coinage to have taken place in Sicily but a short time prior to the above date; presuming, however, that it may have originated 600 B. C., little improvement could be looked for in the course of a century, whereas many Coins of the Prince above-named are of the finest workmanship. It is also highly improbable that a period of two centuries should elapse without any Coins being preserved of the numerous individuals who held the reins of power. Another circumstance will seem greatly to favour the supposition that they were struck in the IIId century B. C., (in which case they may be referred to the reign of Hiero II.) We allude to the portraits appearing in the obverses. It is very doubtful if portraits were introduced on Coins much before the Age of Alexander, at least out of Macedon, and had they been impressed on Syracusan Coins so early as Gelo, there would have remained, in all probability, heads of Agathocles, Phintias, and especially of Pyrrhus, who passed a considerable time in the Island; but none such have been found, the portraits commencing not earlier than Hiero II. The early wealth and prosperity of Sicily is one of the arguments advanced in favour of the older date, but it should be remembered that although Coins, finely wrought, have rarely appeared in any but wealthy Countries, nevertheless, instances are by no means uncommon of Countries proverbial for their early riches, which did not practise the Art of Coinage until the decline of their power. A few silver Coins have been referred to Dionysius, but their authenticity is much doubted; they are inscribed with Phœnician characters, and consequently were struck by the Carthaginians. The Sicilian Monarchic Coins are of various metals and sizes, and of Hiero II. there are a few fine Medallions: this series of Coins closes with the Siege of Syracuse by Marcellus, 212 B. C. The Coins of Epirus commence with Alexander I., a Prince contemporary with Alexander the Great, but with whose History we are little acquainted; the gold Coins which exist of this Monarch are conceived to have been struck in Magna Græcia, whither he went to aid the Tarentines in their wars with Rome. The Coins of Pyrrhus exist in various metals, and offer many pleasing devices.

The remainder of the Monarchic Coins comprise those of a few Princes who reigned in Galatia, Cilicia, Paphlagonia, Heraclea in Pontus, and in Illyria and the adjoining territory.

Value of Grecian Coins.

Little, if any, information can be obtained, at the present day, respecting the *actual* value of money among the Ancients; we propose, therefore, to treat only of the relative value of the pieces when in circulation, by placing upon the chief Coin that value, which it may be conjectured to have borne when struck. This estimate may be effected with considerable accuracy, from the passages remaining in ancient writers who have touched upon the subject, but more especially by the aid of existing Coins. A knowledge of this subject is in a degree requisite in order to understand the terms frequently made use of in Historical works; it must create additional interest in surveying the Coins, which will be augmented as we find a resemblance existing between the weight now employed and such as were then in use.

Silver was used at an early period by the Greeks, being found to be the metal best adapted for the purposes of Coining. The Coins of this metal being the most abundant, their value can be more accurately defined than that of others; they are, therefore, first entitled to consideration.

Silver.

In a former paragraph we remarked that weight was the grand standard of Grecian Coinage, adopted prior to the invention of stamped money, and ever afterwards retained; hence the terms in use to designate the weights were likewise applicable to the Coins themselves. Thus, *Drachma* was applied to a piece of metal weighing the eighth part of an ounce, as at the present day; it retained this appellation after being impressed with a device, and it became the leading denomination of Grecian Coins.

Computation of large sums among the Greeks.

All large sums among the Greeks were referred to so many *Minæ* and *Talents*. The *Mina* is supposed to have been the pound weight of the Country to which it belonged, and was equivalent to the Roman *Libra* or *Pondus*, (hence the term pound,) and to our pound Troy. Eight *Drachmæ* were assigned to the *Uncia*, (ounce,) and twelve ounces, or 96 *Drachmæ*, to the pound; but as it has been customary in all Ages to make an addition to any large sum, the Grecians caused 100 *Drachmæ* to be given to the *Mina*; 60 *Minæ*, or 6000 *Drachmæ*, thereby constituting the *Talent*. The ideal value commonly assigned to the *Drachma* is 9*d*., thus allowing £225 for the *Talent*;* the *Mina*, or Pound, varied considerably in Countries remote from each other; but as it invariably contained 100 *Drachmæ*, the diversity of weight prevailed among these last. The *Talent*, or standard in general use throughout Greece, is that by which many of the early Coins of Asia Minor were regulated, and being afterwards employed at Athens, was designated the *Attic Talent*. Next in importance to this was the *Eginetan Talent*, so called from its originating in the Island Egina; it was employed in Macedon also, and a few Cities of Græcia Propria. The standard which regulated the Sicilian Coinage differed from both the preceding, and has not been satisfactorily explained: the Attic *Drachma* weighed 66 grains, that of Egina upwards of 100 grains.

There was also a second *Talent* occasionally used at Athens, denominated the *Great Attic Talent*, from containing 80 *Minæ*.

Plate I. Fig. 11

The *Drachma* in size is intermediate between our Sixpence and Shilling; and those of the Greek Cities and Kings are common. The Coins of the Cappadocian Princes, and many of those of the Syrian and Parthian dynasties, are of this kind.

Fig. 1.

Didrachmæ are found which may be referred to the Attic standard; those, however, of the Island of Egina are abundant, and some are occasionally met with of those Countries which are mentioned as having adopted the standard of that Island.

Fig. 7. 8.

The *Tetradrachma* is the largest Grecian silver Coin, and is equivalent, as the name implies, to four *Drachmæ*. Those of many Cities are common, of the Kings abundant. The large silver Coins of the Kingdoms of Asia Minor, Egypt, and Syria, are *Tetradrachmæ*. Neither these Coins nor the preceding agree in their sizes, as they are regulated solely by weight; frequently the diameter of the Coin is inconsiderable, in which case the apparent deficiency is compensated by a proportionate increase of thickness.

The *Tridrachma* of the Attic standard, nearly equal to the *Didrachma* of Egina, is a division sometimes spoken of, but as no pieces have yet reached us which we can feel authorized in pronouncing to be of this kind, it is therefore doubtful if there were any struck.

The leading denomination in the silver Coinage, inferior in value to the *Drachma*, is the *Obolus*, forming a sixth part; it is a very small Coin, weighing but eleven grains, and is not of frequent occurrence.

The *Triobolus*, or *Hemi-drachma*, as it is usually termed, is much more common than the preceding Coin; in weight and value it is precisely half of the *Drachma*.

The terms *Diobolus* and *Tetrobolus* are applied to small silver Coins, as their weights with reference to the *Obolus* would seem to authorize the appellations.

The *Obolus* contains eight copper Coins denominated *Chalci*, and its half and quarter being struck in silver were respectively designated *Tetrachalcos* and *Dichalcos*.

The *Dichalcos* is the smallest division of silver money which has been preserved; it scarcely exceeds in its dimensions one quarter of our silver penny, and is about five grains and a half in weight.

Such are the parts of the *Drachma* deserving notice; the reader is, however, cautioned against placing any

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* See the Table.

great reliance on the application of the above terms to the small silver Coins, should they be found even of the required weight; the Athenian silver Coinage abounds of all sizes, and the great assistance afforded by them in ascertaining the constituent parts of the *Drachma* will in some measure compensate for the indifference of their execution and the poverty of their devices.

ld. We now proceed to the gold Coinage of Greece, which is less intricate than the silver, the parts being less numerous and admitting of fewer variations in size.

ite I. g. 9. The leading denomination in this Coinage is the *Didrachma*, called Χρυσοῦς, from the metal, and *Philippus* from having been first coined by Philip of Macedon. Silver, we are informed, at first, bore to gold the proportion of 12 to 1, and afterwards that of 10 to 1, at which standard it continued; hence the *Didrachma* weighing double the *Drachma*, or 132 grains, was valued at twenty silver *Drachmæ*, or 15*s.* sterling.

In the Coinage of the Kings, exclusive of Macedon, the gold Coins of the Syrian Princes, and the few which remain of the Kings of Asia Minor, are *Didrachmæ*.

Next in size to the *Didrachma* is the *Tetradrachma*, according in weight with the chief silver Coin of that name. These are extremely scarce; a few exist of Alexander the Great.

g. 6. The gold Coins of the Egyptian Kings are equivalent to eight *Drachmæ*, or four Χρυσοῖ; they are, however, adapted to a standard with which we are unacquainted, and form no compound of the Attic *Drachma;* they exist of two or three sizes, the smaller ones by their weights being evidently relative parts of the chief Coin.

Octodrachmæ of gold are to be met with of two or three Kings, but they are generally regarded as forgeries.

10. *Drachmæ* in gold exist of a few Cities, and also of the Kings Hiero II. of Syracuse and Pyrrhus; the *Hemidrachmæ* also are not uncommon; they are found in the Kingdom of Macedon, both of Philip and Alexander the Great.

Independently of this enumeration, a variety of gold Coins, yet smaller in size, abound, which are not in conformity to the Attic standard; the remarks on the small silver Coinage are equally applicable in this place.

per. The copper Coins of Græcia Propria, during several centuries, do not much exceed the silver *Drachmæ* in size, and are probably the *Chalci* we have had occasion to allude to. The variety of accounts handed down by Historians, some of whom assign four *Chalci* to the *Obolus*, others six, and a few even ten, has contributed to involve the subject of copper Coinage in great obscurity; and so much disparity prevails among the Coins themselves, as to render the prospect of a satisfactory explanation of them, at this distant period, almost hopeless. This disagreement among Historians may be in some measure ascribed to the proportionate value of copper to silver varying at different periods: eight *Chalci* seem to have been most commonly allotted to the *Obolus*, a number which admitted most readily of divisibility, and hence the quarter of the *Obolus* received the appellation of *Dichalcus*.

Upon the decline of the Greek Empire, about a century after the Age of Alexander, smaller copper Coins were found necessary; hence the *Chalcus* was subdivided into a variety of parts, receiving the general denomination of *Lepta*, the Coin which, according to St. Mark, was cast by the Widow into the Treasury. (xl. 42.) Copper Coins are found of all the Cities of note, and many of them considerably under the size of the *Chalcus;* those of Athens are reducible into four sizes, but any attempt at classing the Coins of the other States in this metal would be fruitless. When the *Chalcus* consisted of eight *Lepta* its parts received appellations indicative of their relative value to that Coin, and thus we have the *Di-lepton* and *Tetra-lepton*, or *Hemi-chalcus*.

Value of Grecian Coins.

Late Coins of the Grecian Empire.

As the dynasties constituting the Greek Empire fell by right of conquest under the power of Rome, the Coins of this last nation became the model upon which those of Greece were formed; such was also the diminution in the sizes of the silver Coins that the *Obolus* was struck in brass, and the *Chalci* substituted in their room. There are many brass Coins of the Island of Chios on which the value is directly specified, as *Obolus*, *Dichalcus*, &c.

The annexed Table exhibits the proportionate value of the Grecian Coins, reduced to the Attic standard, and will serve as an illustration of the foregoing passages; the sizes of the chief Coins may be found by reference to the plates.

MODE OF COMPUTATION.

			£.	s.	d.
DRACHMA			0	0	9
100	MINA		3	15	0
6000	60	TALENT	225	0	0

GOLD COINS.

				£.	s.	d.
Hemi-drachma Τεταρτα-χρυσοῦς.			(5 *Silver Drachmæ*)	0	3	9
2	Drachma Ἡμι-χρυσοῦς.		(10 *Silver Drachmæ*)	0	7	6
4	2	DI-DRACHMA Χρυσοῦς. *Stater Aureus.*	(20 *Silver Drachmæ*)	0	15	0
8	4	2	Tetra-drachma Δι-χρυσοῦς.	1	10	0

SILVER COINS, &c.

CHALCUS.										Weight. grs.	Value. s.	d.
2	Di-chalcus									2¾	0	0¼ & ⅛
4	2	Hemi-obolus								5½	0	0¾
8	4	2	OBOLUS							11	0	1½
16	8	4	2	Di-obolus						22	0	3
24	12	6	3	1½	Hemi-drachma *Tri-obolus.*					33	0	4½
32	16	8	4	2	1⅓	Tetrobolus				44	0	6
48	24	12	6	3	2	1½	DRACHMA			66	0	9
96	48	24	12	6	4	3	2	Di-drachma		132	1	6
192	96	48	24	12	8	6	4	2	Tetra-drachma *Stater Argenteus.*	266	3	0

Metals employed in Grecian Coinage.

It will be found that Gold was not introduced into Græcia Propria or its Colonies, as a medium of commerce, till the most flourishing periods of their History. This observation, which will not apply to either Roman or Modern Coinage, is worthy of notice in this place, inasmuch as the institution of a Coinage in gold in any Grecian City is indicative of its having attained to great opulence. In Asia Minor gold abounded at an early period; it is therefore no wonder that this metal was there resorted to while the Art was in its infancy, which Art, it will be remembered, originated in Lydia, at Cyzicus, Phocæa, Ephesus, Clazomene, and other wealthy Cities. In Magna Græcia and Macedon, gold came into use about the Age of Philip II.; the chief Cities in which it was issued in the former Country were, in Sicily, Syracuse, Panormus, and Agrigentum, in Italy, Tarentum, Metapontum, and the towns of the Bruttii. In the Greek Empire, Macedon, we may observe, rose into power with Philip II., and declined after the Age of Alexander the Great, after which period little gold was struck, copper Coins chiefly abounding. The dynasty of the Lagidæ, whose Country enjoyed a long season of prosperity, have left a fine series of gold Coins. Syria was most powerful under the early Kings, and these are the only Princes of whom Coins in this metal have been found: the gold struck in Asia Minor was coined by the Generals of Alexander and a few powerful Princes, as Antigonus, Demetrius, Nicomedes, and Mithridates the Great. A careful examination of Grecian Coins will convince us that independently of the great body of Historical matter which they comprise, and the numerous passages in ancient writers they elucidate in the most satisfactory manner, they also hold no mean rank among the remains of ancient Art. Numismatical writers have not omitted to notice this circumstance, and the high encomiums which they have bestowed upon them, may have led to an opinion that antiquaries, in their enthusiasm, may have imagined to themselves beauties which in reality do not exist. The difficulty of obtaining access to Cabinets, and the inaccurate representations which have from time to time appeared in printed Works on the subject, might indeed warrant this supposition, but an attentive inspection of the originals will lead the student to confess that, for boldness of relief, freedom and spirit of execution, and correctness of design, they have rarely been surpassed. We must not expect to meet with Coins finished with the beauty and delicacy of ancient Gems, neither shall we find that great degree of neatness characteristic of modern current Coin. To have rendered the margins even, and of a perfect form, could have been effected by a very simple process, but all attempts of the kind either escaped the notice of the Ancients, or were considered as objects of little concern.

Workmanship of Grecian Coins.

We have little hesitation in asserting that Grecian Coins afford a just criterion of the state of the Arts at the periods in which they were struck; there are, however, some exceptions. We should naturally look to Athens for the most beautiful specimens of Coinage, since that State brought the Art of Sculpture to an unparalleled degree of excellence; it will, therefore, excite surprise when we state, that the Athenian Coins are invariably of indifferent execution. In Athens, Coins, it is evident, were regarded merely as objects of commerce; encouragement was held forth by the State for works of magnitude, Temples, and other public edifices, but the art of die-engraving was little esteemed. On the contrary, the Coinage of the Greek Kings, especially the Generals of Alexander, of Magna Græcia, and of Asia Minor, is remarkable for beauty.

Sect. II.—Roman Coins.

Character of Roman Coinage.

From numerous circumstances connected with situation and early History, the Coins of Rome differ in many points from those of Greece; among the distinctions, we may notice the exceedingly large size of the copper Coins struck in the early period of the Commonwealth, the little variety which prevailed in the devices anterior to the reign of Augustus, the greater superiority in the execution of the copper Coins in the Imperial Ages, and lastly, the accuracy with which the sizes were adjusted. It will not be difficult to trace the causes which gave rise to these distinctions. The metals gold and silver were unknown to the Romans in the early period of their History; indeed, mines of silver are to this day rarely to be met with in Italy, while the commerce carried on with the adjoining States was too trifling to admit of an importation of that metal: copper, on the contrary, abounded; it became therefore requisite to coin it of all sizes. It will be obvious that had Coins been struck in Greece of copper equivalent in value to the silver *Drachma*, they would have been of several inches in diameter, and of this kind are the Roman pieces. We have noticed the manner in which the early Grecian Coins were struck; a contrary practice was adopted in Rome, *viz.* that of casting them, as indeed the former method could not have been put in practice with pieces of very large dimensions: when the wealth of Rome was afterwards augmented by foreign conquests, and the copper Coins were reduced in size, by the introduction of silver into the Mint, the practice of casting was discontinued.

Nature of the early symbols.

The symbols first affixed on the Roman Coins were, as we shall shortly see, similar in their nature to those which appeared on the Coins of the surrounding Nations, among whom were many powerful Cities, each of which appropriated to itself some peculiar devices. In the lapse of time these Cities became subject to Rome, and adopted her emblems, but these are little diversified while her conquests were limited to Italy. When speaking of the superiority in workmanship of the copper Coins of the Empire, we should observe that they were for the most part formed of the compound metal brass, which, it would seem, was at that period held in great esteem: these Coins surpass in execution those of copper, as from their larger size they afforded the engraver greater scope for exertion of his skill.

This difference between the Roman and Grecian Coins will oblige us to pursue a different course in our treatment of them. It will be requisite to consider the value of the early Consular Coins apart from the Imperial, and also to specify the value in the outset, since not only are the devices few in number, but a practice long prevailed of designating the pieces of different value by these devices, notwithstanding such pieces were regulated by weight, and impressed with characters denoting their value.

I. Roman Consular Coins.

There are sufficient grounds for believing the Romans to have borrowed the Art of Coinage from their neighbours the Etruscans, Umbrians, and other adjoining States; the Etruscans were powerful and opulent long before the building of Rome; sufficient monuments exist to this day which prove them to have been a highly polished Nation, and to them probably all the earliest

Italian Coins may be referred. Herodotus relates[*] that a Colony of Lydians planted themselves at an early period in Umbria, whence it has been inferred that the Romans, through the medium of the Umbrians, were, as well as the Greeks, indebted to Lydia for the invention of the Art. We are not, however, warranted in this conjecture, as it seems very doubtful if the Art was known in Asia Minor until long after the period of the above-named migration. The Cities in that part of Italy of which numerous Coins are extant are Volaterra, in Etruria; Tuder, in Umbria; and Hatria, or Hadria, the City which subsequently gave name to the sea on the coast of which it was founded: many Coins likewise exist of the Cities Populonia and Teate, situated in the Countries above named, but they are of later date. The symbols appearing on these Coins, executed in the most wretched style of Art, are very various, and as they seem in no way connected with the Cities themselves, any detailed account of them will be superfluous: the common devices are Cattle, (hence the origin of the term *pecunia*, from *pecus*,) a variety of Animals, Fish, Anchors, Wheels, Bones, &c. The names of the Cities are generally given in characters peculiar to the Country, and slightly resembling the Phœnician; there are also certain marks indicative of their value. The chief pieces in circulation were rude masses of copper, most frequently of a circular form, of several inches in diameter, and weighing about a pound; the pound was divided into twelve ounces, and each of the smaller denominations contained a certain number of ounces, the precise number being designated by points or dots.

stitution
Coinage
Rome.

Coinage, as we are informed by Pliny,[†] was instituted at Rome under the reign of Servius Tullius, 550 B. C., or according to Newton, 467 B. C. This Coinage consisted of the *As Libralis*, (from *as* or *æs*, brass,) or *As* of a pound weight, and, after a short period, of its parts, each of them receiving a name expressive of its value with reference to the chief Coin. They will arrange themselves as follows:

As Libralis .... containing	12 oz. its character	L or I.
Semis, half of the ***As***......	6..............	S.
Triens, one-third ditto.....	4..............	••••
Quadrans, one-quarter ditto	3..............	•••
Sextans, one-sixth ditto....	2..............	••
Uncia, one-twelfth ditto...	1..............	•

bols on
uscan
Roman
s.

The symbols at this period were very similar to those on the Coins of Etruria, Umbria, &c., but in a few years heads of the chief Deities were introduced. It will be remembered that the Grecian Civic Coinage underwent a somewhat similar change when the indentations were no longer needed; the Deities would indeed naturally suggest themselves as the most appropriate emblems. The Gods of the Romans derived their origin from the early Kings of Italy: first in order is Janus, who was succeeded by Saturn, for a period indeed they reigned conjointly; the third Prince was Picus, also called Jupiter, after whom came Faunus, or Mercury: these were regarded as Deities, were especially honoured at Rome, and upon the extension of her conquests became incorporated with those of Greece.

ls on

When, after the lapse of half a century or more, the States in the vicinity of Rome declined in power, their Coinage insensibly disappeared, while that of Rome assumed a character of its own; and the *As* and its parts each had devices appropriated exclusively to them. Hence we have the Goddess *Roma* (accoutred like the Grecian Pallas) as the first instance on record of the personification of a City, a practice afterwards carried to a great extent, as we shall perceive when the Imperial Coins fall under consideration. The following are the symbols at the period in question:

Roman
Consular
Coins.

As, head of Janus.		*Quadrans*, head of Hercules.	
Semis	Jupiter.	*Sextans*	Mercury.
Triens	Minerva.	*Uncia*	Roma.

Symbols on
the reverses.

The double face given to Janus has not been satisfactorily explained; he was often confounded with Saturn, or Time, and was probably represented under this form as presiding over time past and future. The prow of a galley, which is the common, and for a considerable period constituted the sole, type on the reverses of the *As* and its parts, was adopted in commemoration of Saturn, who came by sea to the shores of Latium, instructed the rude inhabitants in agriculture, and was associated by Janus in the Government of the Country.

Diminution
in the size
of the As.

Such was the character of the early Roman Coinage; the changes it subsequently experienced, and the progressive stages of improvement which it underwent, were the fruits of time, the result of circumstances and of political emergency. A constant diminution is observable in the sizes of Coins in proportion to the political advancement of the Country which employs them; for as a Nation rises into importance, its demands necessarily augment, and the readiest method which presents itself of meeting the exigencies of the State consists in reducing the size of the chief Coin in circulation, yet assigning to it a value equivalent to that which it had borne before such a reduction took place. Upon the commencement of hostilities with the Carthaginians, from the expenses attending a war in a foreign Country, the *As*, as Pliny informs us, did not exceed two ounces in weight; its parts had, of course, decreased in like proportion. This diminution may also be ascribed to the introduction about that period of silver into the Mint; and as the Roman *As* and its divisions, recognised by the devices above specified, have been found of all sizes intermediate between the pound and two-ounce weights, we may fairly presume the reduction to have been gradual.

Compounds
of the As.

At the period during which the *As* was three and four ounces in weight, and previously to the coining of silver, an inconvenience appears to have arisen from the want of Coin above the value of the *As*; hence pieces of larger denominations were struck, weighing double, treble, and quadruple of the *As*, and designated by the terms *Dupondius*, or *Bissas*, *Tripondius*, or *Tressis*, and *Quadrussis*. These Coins are not of frequent occurrence, and may be distinguished from the *As* and its parts of an early date (some of which equal them in weight) by the characters impressed upon them; all the reverses bear the symbol of the prow, and the obverses the head of Pallas, or possibly Roma; for they are often confounded by the ablest antiquaries. The *As*, we have stated, bore the character I, to denote its value of one pound, and this mark it retained when reduced to a few ounces in weight; the relative value of the *Bissas* was expressed by two of these strokes, the *Tressis* by three, and so on. The inconvenience which must have arisen from the size of these Coins, was probably the cause that so few were issued from the Mint; but, notwithstanding this circumstance, two or three pieces are known to exist equivalent in value to ten *Asses*; they

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[*] i. 94.

[†] xxxiii. 3

are of the same date with the preceding, of about six inches in diameter, and are impressed with the numeral X denoting their value.

Further diminution of the As.

The *As libella*, as it was termed in its diminished form, experienced a further reduction to one ounce in weight during the IId Punic War, and again about 175 B. C., when it did not exceed half an ounce; at this standard it remained until the close of the Commonwealth. These successive changes had so much operated to diminish the parts of the *As* in size and value, that they were frequently discontinued, and with the last reduction the *Sextans* and *Uncia* altogether ceased.

Coins of the Families.

Soon after the introduction of silver into the Coinage, a practice became general of affixing the names of the chief families in Rome (probably intended as a compliment from the Mint-master) in the field of the Coins: they are consequently distinguished by the appellation of *Family Coins;* the name of the City also formed part of the Legend.

Arrangement of the Roman Asses.

From the peculiarities which characterise the Roman copper Coins, and the fluctuations they experienced in value, we may regard them as consisting of three kinds; the first of these extends from the reign of Servius Tullius until about 400 B. C. The Coins during this period are unwieldy pieces of metal, excessively rude in their fabric, and bearing a variety of devices, the emblems of the Etruscan and Umbrian Cities being used in common with those of Rome. The next division extends to 250 B. C., or about the middle of the Ist Punic War; these are of improved execution, and the types few in number, one device being appropriated to the *As*, and to each of its parts. The third and last kind extends to the Augustan Age; they are considerably reduced in size, of superior workmanship, and are greatly diversified in their symbols.

Institution of a Coinage of silver.

We now arrive at the silver Coinage of Rome, first introduced in the Capital 266 B. C. The form in which silver first appeared, was that of the *Denarius*, so termed from its value of ten *Asses*. These therefore supplied the place of the *Decusses*, or large copper Coins above alluded to. The earliest of these Coins weigh about ninety grains, and represent on the obverse the double-faced head of Janus, on the reverse Jupiter in his car, hurling his thunderbolts; these pieces were, however, soon dropped, and replaced by the *Denarius* of sixty-six grains, the *Quinarius*, or its half, of five *Asses*, and the *Sestertius*, a word employed by the Romans to express two parts of an integer and *half of the third;* thus in the present instance it formed one-quarter of the *Denarius*, containing two *Asses* and a half. The symbols affixed to the obverses of all these Coins were heads of the Goddess Roma, with wings on the helmet, (which distinguishes it from the head of Pallas,) and the upper part terminating in the head of a griffin. For the reverses two devices prevailed; the first of these were the twins Castor and Pollux, the other a Car of Victory. The Demigods Castor and Pollux were greatly honoured at Rome, and had their Temples in the city; this worship had its rise from a tradition that in the infancy of the Republic they aided the Romans in a battle with the Etruscans fought at the lake Regilla. They are represented on horseback precisely resembling each other; the stars placed over their heads imply their deification. The Car, guided by a figure of Victory, is a more common symbol; it is sometimes drawn by two and sometimes by four horses; hence the pieces were denominated *Bigati* and *Quadrati*. The characters constituting the Legend were for a considerable time limited to the name of the City, and the marks indicative of value; the *Denarius* bore the numeral X, which was afterwards converted into a *star*, and subsequently disappeared; the *Quinarius* bore the Roman character V; and lastly, the *Sestertius* IIS, to denote its value of two *Asses* and a half; the two lines were afterwards united thus HS. In a short time the names of the families were placed on the reverse, as on copper Coins of the same period.

Plate I. Fig. 17.

Fig. 20.
Fig. 21.
Fig. 22.

Fig. 22.

Fig. 19.

Roman Consular Coins.

Symbols on the Denarii.

A considerable time elapsed before these devices fell into disuse, but foreign conquests and the consequent influx of Grecian Coins at length enlarged their number; in lieu of the head of Roma we find representations of the chief Grecian Deities, who now became incorporated with those of the Eternal City; and thus are seen the effigies of Venus, Diana, Mars, Apollo, Ceres, Bacchus, &c., which, as they are generally accompanied by their attributes, may readily be recognised. On the reverses of the *Denarii* numerous emblematical and historical figures appear, but as the variety among these is almost endless, we shall not attempt an enumeration of them; it will be requisite for us to enter at some length into the symbols of the Imperial Coins, to which, as they nearly resemble many of the above, the reader is referred. One class of devices remains to be noticed, *viz.* the heads of Generals and Consuls, which at a late period supplanted those of the Deities. These representations were affixed by their descendants and by the Mint-masters, being either dictated by flattery, or designed to record their most important services while in office, in which case the events themselves were depicted on the reverse.

Arrangement of the silver Consular Coins.

The silver Coins of the Republic may, like the copper, be distinguished into three classes; the first, including the Coins bearing the heads of the Goddess Roma, the Car of Victory, and the Twins. Some idea may be formed of the number of these, when, if Pinkerton be tolerably correct in his computation, they comprise ten-twelfths of the silver Coins. Those of the second division bear the heads of the chief Deities, and a variety of emblematical and historical figures; and the last, including but a very small number, is distinguished by the portraits of the Generals, Consuls, &c. with reverses like the preceding. In order to convey some notion of the immense number of Family Coins known to exist, it will be sufficient to state that they have been found inscribed with the names of nearly two hundred families, and, in a few instances, one hundred and fifty varieties to a single family. At the time in which an alteration was effected in the symbols, and heads of distinguished characters were introduced, their names were inserted in the Legend together with the office they held in the State, whether that of Consul or Proconsul, Quæstor, Imperator, or Triumvir.

Institution of a gold Coinage.

A Coinage of gold was instituted at Rome sixty years after the introduction of silver, and the pieces issued were of three kinds; *viz.* the *Scrupulum*,* weighing one-third of the *Denarius*, a Coin of double this weight, and the third equalling the weight of the *Denarius*, then of sixty grains. The head of Mars and an Eagle are the devices appearing on all these Coins; the name of the city ROMA is also inserted, and characters denoting their weight, and their value with reference to the *Sestertius*. As these three Coins are rarely to be met with

Plate I.
Fig. 23.
Fig. 24.
Fig. 25.

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* Plin. xxxiii. 3.

Numismatics.

in Cabinets, they are introduced in Plate I., where the marks alluded to will be seen; the first of the two characters on the largest piece corresponds with the Roman numeral L. It will be proper in this place to remark that many antiquaries are averse from classing these with Roman Coins; but notwithstanding, as in their workmanship they resemble the Coins of Magna Græcia, as they perfectly accord with the accounts transmitted to us by Pliny of the earliest gold Coins of the Republic, there can be little doubt to which Nation they belong. The whole of Magna Græcia had been long subject to Rome, the brightest period of its Coinage had passed away, and the most skilful of the die-engravers probably centred in the Capital: the name of Roma likewise appearing seems to be conclusive.

w Coin- of Gold.

This new Coinage, from the few pieces which have been discovered, must have been speedily dropped, and, judging from the distinct character of that which succeeded, it would seem that a considerable period elapsed before gold again circulated as the medium of commerce. The chief gold Coin afterwards issued was the *Aureus*, named from the metal, as the Greek *Chrusos* and *Chalcos;* together with the *Aureus* there appeared likewise its half, denominated *Quinarius*, *Semissis*, and *Semi-Aureus*. *Quinarius* was so called from being of the same dimensions as the silver Coin of that name, but it is surely misapplied. The *Aureus* is of twice the weight of the *Denarius*, though equalling it in size; the date of its appearance at Rome is unknown; as, however, both this Coin and its half, especially the latter, are of great scarcity under the Commonwealth, and as, moreover, they are impressed with symbols similar to those on the late *Denarii*, we shall not greatly err in referring the earliest of them to about 100 B. C.

ration he value he De- us.

A material alteration took place in the value of the *Denarius* at a late period of the Commonwealth, which affected all the Coins of inferior value. This change Pinkerton conjectures to have occurred 176 B. C.; the *Denarius*, which had hitherto consisted of ten *Asses*, (as indeed its name implies,) was ordered to pass for sixteen; the *Quinarius*, in consequence, was rated at eight, and the *Sestertius* at four *Assaria;* the names were nevertheless retained, an inconsistency scarcely to be avoided, and which has prevailed with the Coinage of almost every Country. A few *Denarii* are impressed with the numeral XVI. on the obverse, which may possibly have had reference to their change in value, but on which no reliance can be placed, as various numbers were from time to time inscribed. It is remarkable that the issue of the *Sestertius* in brass, after having long circulated in the form of a small silver Coin, should have escaped the observation of Medallists until within the last few years. Pinkerton, in his *Essay*,* has pointed out, in a very satisfactory manner, the changes it underwent, before it came to be considered as the leading Coin, and that by which all large sums among the Romans were estimated. The *Sestertius* does not appear to have been struck in brass immediately upon the alteration in the value of the *Denarius*, as few of them have been found before the Augustan Age; the *Sestertius* may have circulated in silver during the Commonwealth at the value of four *Asses*, until, from the decreasing value of that metal, it had experienced such a diminution in size as to be productive of great inconvenience. The symbols on the *Quinarius* and *Sestertius*, upon their first appearance, perfectly resembled those of the *Denarii;* but they were subsequently varied; a head of Jupiter and a figure of Victory constituted the types of the former piece, whence they were denominated *Victoriati*, and a head of Mercury, with the Caduceus, those of the *Sestertius:* these last are of great scarcity, probably owing to their diminutive size.

Roman Consular Coins.

General survey of the Coins of the Commonwealth.

In the course of our remarks upon the Imperial Coinage, we shall briefly notice the changes to which the class of Coins just described became subject; but enough has been said to show that they are of themselves capable of bringing us acquainted with the gradual increase of the Roman power, from the period when its territory comprised but a few miles in extent, to that at which it aspired at universal dominion. Thus if we examine the most ancient Roman Coins, those reported to have been fabricated under the reign of Servius Tullius, we find them to be of the most barbarous execution, with the devices scarcely intelligible: they were evidently the fabrication of a rude, unpolished nation, which totally disregarded the cultivation of the Arts. We learn from History that Rome was for many centuries but a warlike city, its inhabitants inconsiderable, and the existence of the State itself precarious. The Coins just mentioned bear not the slightest resemblance to those of Greece, whence we infer that hitherto no intercourse had subsisted between the two Nations; on the other hand, they closely resemble the Coins of Etrurian Cities and the adjoining States, by which we learn that Rome was in communication, and perhaps alliance, with them. After the lapse of a few years, we find the symbols adopted by the neighbouring Nations fall into disuse; from which circumstance we may conclude that either they subsisted under the protection of Rome, or were annihilated by her in her conquests. The progressive stages of their decline, might, we conceive, be ascertained with some accuracy, were greater attention bestowed on this curious class of Coins, but from their general rudeness, and the uncouth representations they bear, they are too frequently disregarded. If the diminution in the size of the Coins can be proved to have been gradual, their weights would enable us to ascertain their respective eras, though unfortunately, from their long continuance underground, and from accidental injuries, they are seldom found in a perfect state, and much is consequently left to conjecture. To return to the present view of our subject, the gradual reduction in the size of the Coins indicates a proportionate increase in the wealth and power of Rome; and upon arriving at the Ist Punic War, we may reasonably infer from the Coins, that a communication now subsisted with some foreign power,—a new metal is introduced in the Coinage, and the execution of it is considerably improved. This last circumstance was probably caused by the conquest of Sicily and the Southern part of Italy, Countries in which the Art had long attained to maturity. If we descend to a yet later period, that at which Greece was formed into a Roman Province, we shall find, on viewing the Coinage, an infinite variety in the devices, while the execution in gold and silver is far superior to all that had yet appeared; we are thereby informed that their commerce was greatly extended, and that the conquest of Greece had caused an influx of works of Art from that Country, and probably of the artists themselves.

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* *Essay on Medals*, sec. 7.

The following Tables, exhibiting the fluctuations in value of the Coins of the Commonwealth at different periods of its History, are introduced to elucidate the preceding remarks:

About 300 B. C.

							Uncia.
2							Sextans.
3	1½						Triens.
4	2	1⅓					Quadrans.
6	3	2	1½				Semis.
12	6	4	3	2			As.
24	12	8	6	4	2		Bissas. *Dupondius.*
36	18	12	9	6	3	1½	Tressis. *Tripondius.*[*]

About 200 B. C.

								Weight. oz.	grs.	*Value.* s.	d.
							As	1	0	0	1½
2							Dupondius	2	0	0	1
2½	1¼						Sestertius	0	15	0	2
5	2½	2					Quinarius	0	30	0	4
10	5	4	2				DENARIUS	0	60	0	8
50	25	20	10	6⅔			Scrupulum	0	20	3	4
100	50	40	20	13⅓	2		Tremissis	0	40	6	8
150	75	60	30	20	3	1½	Semissis†	0	60	10	0
Copper.		Silver.			Gold.						

II. Roman Imperial Coins.

The Imperial Coins of Rome form the most complete, and, we may perhaps say, the most interesting series extant; from the great diversity of the symbols a classification of them is attended with much difficulty, yet as there are no other means of acquiring a knowledge of them, we shall resort to that method of arrangement, which, in the present case, will be somewhat elaborate.

Arrangement of the symbols.

All the symbols may be arranged under four heads, as shown in the annexed Table; in which, also, the various subdivisions of the classes are specified. It is almost needless to observe, that the Deities, Moral Virtues, &c. are too numerous to be specified in the Table. The same order will be preserved in the observations which follow, explanatory of the various modes in which the effigies, ceremonies, &c. are delineated on the reverses.

- Symbols relating to .. The Religion of the Romans .....
  - Religious ceremonies ...
    - Sacrifices.
    - Consecrations.
    - Instruments of Sacrifice.
    - Miscellaneous.
  - Heathen Mythology ...
    - Deities.
    - Personifications ....
      - Moral Virtues, and other Allegorical subjects.
      - Divisions of the World, Countries, Provinces, Cities and Rivers.
- War ....
  - Representations of the several forms observed by the Romans in conducting their wars.
  - Implements of warfare.
- Games .....
  - Chariot races.
  - Combats with wild beasts.
  - Naumachiæ.
- Embellishments of the City ......
  - Buildings appropriated to religious purposes.
  - ——— relating to warfare.
  - ——————— the Games.
  - ——— of a miscellaneous kind.

I. Symbols relating to Religion.

The representations of Sacrifices, in which a Priest is seen offering up a victim in front of a Temple, and attended by his inferior officers, are highly interesting, as they afford a great insight into the manner of conducting these ceremonies. The Consecrations are variously depicted; they allude to a practice very prevalent at Rome, that of deifying the Emperors and Empresses after their death. An Eagle, as the bird of Jupiter, generally expressed the deification of an Emperor, and a Peacock, the bird of Juno, that of an Empress; over the figures *Consecratio* is inscribed. The other devices which denoted a deification were the Funeral Pile and the *Thensa*, or divine chariot; the former of these was constructed on a very magnificent scale, adorned with hangings, and upon it the Emperor was burned in effigy: the latter represented the chariot in which the Gods were carried in the religious processions. The Instruments of sacrifice consisted of Altars and Tripods, the last being designed for liquid offerings, and those which were conducted without the Temples; they are frequently placed on Coins, to denote the piety of the Emperor, in which case they are accompanied by the Legend *Pietas*. Instruments of sacrifice are frequently placed on the reverse for the same purpose. The instruments commonly introduced were an axe for slaying the victim, vessels containing the holy water for sprinkling the offering, a *Patera*, or kind of plate, on which were placed the portions consecrated to the Gods, and, lastly, the *Accerra*, or censer. Plate II. Fig. 1.

Figures of the De

The Deities are represented at full length, accompanied by their attributes: thus Venus bears the apple, Ceres, torches, Isis the sistrum, and Mars a trophy on his shoulder; this last figure is conceived to have been designed for Romulus. Jupiter Capitolinus is represented seated within his Temple; in his right hand he bears a sceptre, and in his left hand the thunderbolt. Vesta is represented veiled, after the manner of her own Virgins; in one hand she bears a sceptre, indicative of her divinity, and in the other the *Palladium;* a small figure of Pallas, on which, according to tradition, the fate of Troy depended, and which, upon the destruction of that city, was secured by Æneas, brought to Rome, and

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[*] The *Quadrussis* and *Decussis* are of very rare occurrence. The weights are not inserted in this Table, as they cannot be ascertained with any precision; the *As* at this period was of from two to three ounces.

The *Quincunx*, containing five ounces, was sometimes coined.

† The parts of the *As* as before. The terms *Semissis* and *Tremissis* are introduced with reference to the *Aureus*, struck some time after.

te II.
. 9.

consigned to the care of the Vestals. The Goddess Roma is of very frequent occurrence on Imperial Coins, in which she is represented seated on a pile of arms, to denote her achievements in war; she is armed after the manner of Pallas; in her right hand is sometimes a globe, as the emblem of universal dominion, and at other times a figure of Victory; a sceptre is occasionally found in her left hand, but more commonly a sword.

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s and
gorical
ures.

Among the Moral and Allegorical Figures, Hope, Piety, Peace, and Eternity are chiefly deserving of notice. Hope, the most common personification, is represented holding her dress with her left hand, that it may not impede her in her march, it being characteristic for Hope to press forward to the attainment of her object, as it is of Fear to recede; in her right hand she bears the bud of a flower. Piety is always represented veiled, as was the practice with females when engaged in the performance of any religious rite; she appears casting incense on an altar from a censer, which she bears in her left hand. Under this personification we may sometimes trace the origin of our modern representation of Charity, the figure of Piety being frequently attended by children, to imply that Piety to our Creator is best shown in our good deeds to one another. When the above attributes are omitted, the Stork, from the legendary attachment of that bird to her offspring, is introduced as symbolical of the duty of children to their parents. Peace is a common personification, and is similar to the modern representation of it; the cornucopia is, with scarcely an exception, placed in her hands, and in addition, we have the trite emblem of the olive branch. Eternity occurs less frequently, and is variously depicted: sometimes she is veiled, and bears a sceptre; a globe is frequently placed in one hand, surmounted by a Phœnix, with the head encircled by rays, it being the offspring of the Sun. Eternity is also figured bearing in her hands the Sun and Moon. The attributes of a few of the Deities and Moral Virtues are not unfrequently placed alone on the field of the Coin; wherever this occurs, they may, in most cases, be understood to bear the same signification as when associated with the figures: a cornucopia, for example, denotes the plenty which prevailed during the particular Emperor's reign; two of them, perhaps, signify an extraordinary plenty. The caduceus standing alone forms a common reverse, and is a symbol of Peace. We may also mention the Virtues Concord and Fidelity, represented under the form of two hands joined. The good-will which existed between the Emperor and his people was represented by the former taking the hand of one of his chief officers. It was not unusual to combine two or more symbols of this kind on a single reverse; the Romans, indeed, frequently indulged in this kind of Poetical imagery; the practice prevailed chiefly in the Augustan Age, and thus upon Peace being established between Augustus and M. Antony, a Coin was struck, on which appear two cornucopiæ, supported by hands joined, and between them a caduceus. Augustus was born under the sign Capricornus, which he therefore represented on his Coins; he employed a Globe to signify possession of the world, and a Rudder to denote rule; all of these types appear united on the Coins of that Emperor.

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&c.

We next proceed to the figures of different Countries. Europe was represented by Europa and the Bull; for Asia a portion of a vessel was introduced, that being the quarter of the Globe in which Navigation was said to have been first practised; Africa offers a very complete personification, she appears in a helmet formed by the proboscis of an elephant, in one hand a scorpion is placed, and in the other a cornucopia; a bull is sometimes introduced to denote that Agriculture formed the chief employment of the natives. The ibis denoted Egypt, and the camel Arabia; to Spain was assigned an olive branch, and a bow and arrows to Parthia. Among the Provinces, the personifications of Judæa and Britannia are remarkable. Upon the destruction of Jerusalem by Titus, 70 A. D., numerous Coins were struck, on the reverses of which the Genius of the City appears bewailing the calamity which has befallen it; she is veiled, expressive, in this instance, of distress, and seated on the ground, an attitude implying captivity; behind the figure a palm tree is introduced, it being the growth of the Country; also a Hebrew captive with his hands tied. In the personification of our own Island, as it has been preserved on a small number of Imperial Coins, we have the origin of the Britannia affixed on the modern current Coin. The figure sometimes bears in her hand a Roman standard, denoting that the Country was a Province of the Empire; she sometimes appears armed, (as on our existing copper money,) indicative of the warlike disposition of the natives. There is also a Coin on which the figure of Britannia is seated on a globe, with waves rolling at her feet. As the above Coins are possessed of more than ordinary interest, the reader is referred to Pinkerton's *Essay on Medals*, in which will be found engravings of six out of ten, all that in his time were known to exist. There are frequent allusions on Roman Coins to the victories obtained over the early Britons, which are represented by a Triumphal Arch, with the legend *Britannia*. In the last division of this class are the Rivers: the Tiber is recognised by the introduction of the twins suckled by the wolf. It is worthy of observation, that the Romans have invariably represented the River Gods in a reclining attitude. The Nile holds a cornucopia in his hand; he is sometimes represented reclining on an urn, from which water is issuing, and the mouth of it partly concealed by drapery. Two animals usually accompany this personification, the Crocodile and the Hippopotamus.

Origin of
the figures
of the Provinces on
Roman
Coins.

Figures of the Provinces are not common until after the Augustan Age; the circumstances which gave rise to their adoption are various, as upon a new Province being annexed to the Empire, upon the Emperor recovering one which had been overrun by the Barbarians through the indolence and apathy of his predecessors, and also upon an Emperor visiting Provinces remote from the Capital, or making the circuit of his dominions. Reverses thus engraved, therefore, cease with the decline of the Empire, when the Barbarians of the North had so firmly established themselves on the frontiers, that all attempts to repel them were ineffectual. The most considerable of Trajan's conquests were the formation of Dacia into a Roman Province, and the reduction of Armenia, Mesopotamia, and Parthia: all which acquisitions were severally recorded on his Coins. The Emperor Hadrian made a complete circuit of his dominions, and his Coins have been found inscribed with the names of no fewer than twenty Provinces. The Emperors Claudius, Hadrian, Antoninus Pius, Septimius Severus, and Commodus, who carried their arms into Britain, have had that conquest recorded on their Coins, by the figure of Britannia as above described. Pope has delineated in very polished and harmonious verse this system of Coinage.

> Ambition sigh'd, she found it vain to trust
> The faithless column, and the crumbling bust;
> Convinc'd, she now contracts her vast design;
> And all her triumphs shrink into a Coin..
> A narrow orb each crowded conquest keeps;
> Beneath her Palm here sad Judæa weeps;
> Now scantier limits the proud Arch confine,
> And scarce are seen the prostrate Nile and Rhine.
> A small Euphrates through the piece is roll'd:
> And little Eagles wave their wings in gold.

2. Symbols relating to war.

Various circumstances connected with War, each accompanied by an appropriate Legend, are frequently represented on Roman Coins. The Emperor is sometimes seen haranguing his soldiers; the Legend *Adlocutio* illustrating the device. The departure of an expedition was always attended with great pomp, prayers and sacrifices being offered up for its success; this circumstance is recorded on the Coins, with *Expeditio* for the Legend. The expedition is also occasionally represented crossing a river either by vessels or a bridge, when the Legend *Trajectus* is introduced; and lastly, we have the return and triumphal entry of the Emperor or General, who appears in a chariot attended by Victory; the Legends accompanying this device are *Triumphus* or *Victoria.* The reception of the Emperor at the several stations was expressed by the Legends *Adventus* and *Profectus* accompanying the device: in the latter case the Emperor is attended by one or more of his chief officers; and in the former by the Genius of the City, at an altar, offering up a sacrifice in gratitude for his safe arrival.

The implements of warfare consist of Standards, Shields, Cuirasses, and Trophies; Heaps of arms also appear as tokens of victory. Victory also is frequently seen recording on a shield the conquests of the Generals or Emperor. A Warrior is often the type of the reverse, also the Roman Eagle, and Laurel branches. The Crowns represented on Coins are of two kinds; the Rostral Crown, which rarely occurs, and the Oaken or Civic Crown, common on Coins of Augustus, and within which the words *Ob cives servatos* are inscribed. This Crown, it will be remembered, was awarded to such as had saved the life of a Roman citizen; and though we are not to take this in the literal sense, when applied to the Emperor, he may nevertheless be considered as entitled to that honour, by having established Peace throughout his dominions.

3. Symbols relating to the Games.

The number of devices relating to Games is very inconsiderable, and they were, for the most part, affixed to the Coins of those Emperors who were addicted to those Festivities. Naumachiæ are occasionally representations.

4. Symbols relating to the embellishment of the City.

Temples are depicted on the Coins of nearly all the Emperors. Those of Jupiter Capitolinus and Janus are of common occurrence; the latter being a small, square shrine, just sufficiently capacious to contain a Statue of the God. On the Coins of Augustus appear the Temples erected by that Emperor in honour of Apollo, Juno, Mars, and Julius Cæsar; generally the porch only of the Temples is represented, and within it is placed a small Statue of the Deity. Triumphal Arches are very common devices, and in the event of a foreign conquest were immediately affixed on the Coins; they are inscribed with the name of the conquered Nation, and adorned with trophies. The Column of Antoninus Pius, now standing, is a common type on his Coins. The Rostral Column appears on Coins of Augustus, in honour of the Battle of Actium. Equestrian Statues, erected to many of the Emperors by the Senate and Roman People, in consideration of their services to the State, are delineated on the reverses of several Coins.

Plate II. Fig. 1

Roman Imperial Coins.

Representations of the Theatres, Amphitheatres, and Circuses are preserved on a few Imperial Coins, but they are by no means common. The Forum of Trajan is found on one of his Coins; and Basilicæ, Baths, Ports, Bridges, and Aqueducts were occasionally introduced.

Having concluded our summary of the devices, (in which enumeration all that merit the attention of the general reader have been specified,) we shall proceed to notice the Legends, of much greater extent on Roman than on Grecian Coins.

Legends on Roman Coins.

We have already enumerated several of these in our description of the symbols; and, indeed, the characters on the reverses of the Coins are little more than explanatory of the type; thus the Allegorical figures, though they may be readily known from being accompanied by their attributes, have their names introduced: the same may be observed to be the case with the figures of the Provinces. In the Legends accompanying these last, we perceive the Roman Tongue to be admirably adapted for recording events, where brevity of expression is important; the following examples are remarkable for their comprehensiveness: *Judæa capta, Salus Generis humani. Gaudium Reipublicæ. Asia subacta. Tellus stabilita. Roma renascens.* But what is now to engage our attention, is the characters inscribed on the obverses, to which the portraits of the Emperor or Empresses were affixed. Upon the first inspection of a Roman Imperial Coin, we are apt to imagine that the Legends cannot be deciphered without much difficulty; and, indeed, it must be granted that great confusion prevails from the numerous abbreviations, and the deficiency of stops. In order to convey to our readers a clear idea of their nature, we propose to analyze, if we may so express ourselves, the Legend of an Imperial Coin; and we select for that purpose one of the Emperor Titus. It will be perceived, on examination, that the titles conferred on the early Emperors were used in common by their successors; and these being, therefore, once understood, a large portion of the Legend of almost any Imperial Coin will be known. When the characters encircle the device, they form what is denominated the *Legend;* when they occupy the field of the Coin, they constitute an *Inscription;* and when occupying the lower extremity of the piece, and separated from the area by an horizontal line, they are termed the *Exergue:* (ἐξ ἐργȣ͂, out of the work:) the date on the reverse of our English copper Coins generally occupies this station. Before proceeding to examine the Coin we have selected, we will briefly specify the titles commonly annexed to the Throne, and whence they derived their origin. The title *Imperator*, or Emperor, was under the Roman Commonwealth a military distinction, answering in some measure to General with us; it was subsequently conferred upon Octavius by the Senate, to denote the supreme power in the State, and came into general use with his successors. This title was expressed on the Coins simply by the three first characters, IMP. About the Age of Constantine the Great it fell into disuse, that of *Dominus Noster* being substituted; the initials D. N. are all that appear on the Coins. The appellation of *Cæsar* originated in the Julian family, in consequence of one of them having had in his possession an elephant, which animal in the

Plate II. Fig. 3.

Fig. 2.

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Punic Tongue is expressed by that word. It was assumed by all the descendants of that family, and after so long a period seemed in a manner inseparable from the Throne. The title *Augustus* was conferred by the Senate on the young Octavius, at his express desire: it was borne in his honour by all the successors to the Empire, as was also that of *Augusta* by the Empresses, and it was expressed on Coins by the three first letters, AUG. The power, equivalent to that of a Tribune, which was conferred on Augustus, was expressed on his Coins by the words *Tribunitiâ Potestate*, or more generally in the abbreviated forms TRIB. POT. and TR. P. The election to the above office was annual, and as the Emperors (except in one or two instances) were elected immediately on their accession, wherever numerals are annexed they denote the year of the Prince's reign. The glorious title, *Pater Patriæ*, or Father of his Country, expressed by the initials P. P., was accorded with great propriety to the Emperor Titus; the distinction, it must be confessed, was rarely merited by his successors, but being calculated to flatter their vanity was seldom omitted. Among other epithets, equally misapplied in aftertimes, was that of *Pius*, originating with the first Antoninus, one of the most perfect characters to be found in History. The office of High Priest, or Superintendent of the Pontiffs, was assumed both by Julius and Octavius upon their coming into power; it is frequently inscribed on their Coins, and, like the preceding titles, was retained by their successors. It was expressed by PONTIFEX MAXIMUS, though commonly abbreviated, as PONT. MAX., and P. M. The office of *Consul*, assumed by the Emperors, was signified by the three letters COS. If we now inspect the Coin of Titus, represented in Plate II., many of the above titles will be found inserted in the Legend; the following is the order of the characters, the names and titles being given at full length. *Imperator Titus. Cæsar Vespasianus Augustus. Pontifex Maximus. Tribunitiâ Potestate. Pater Patriæ. Consul VIII.* The letters S. C., *Senatus Consulto*, affixed invariably to the Imperial Coins in first and second brass, denote that they were struck by a decree of the Senate; to that Body was decreed the power of striking brass Coins, and to the Emperor those of gold and silver. The above characters consequently never appear on the Coins in these latter metals.

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Upon the dissolution of the Greek Empire, the several Countries were formed into Roman Provinces; over each of these a Governor was appointed, and a Coinage instituted in the chief Cities. These Coins are inscribed with Greek characters; they class notwithstanding with those of Rome, from being struck in Countries subject to that Empire, and from bearing heads of the Emperors on the obverses: in point of execution, the Coins of this class are very inferior to those which were issued from the Capital.

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The Imperial Greek Coins divide themselves according to the forms of government instituted by the Romans in their conquests; and thus we have Provinces, Colonies, and *Municipia*, or Free Cities. These are all the workmanship of inferior artists, and exhibit great sameness in the devices, which are for the most part included in the enumeration of the symbols on Imperial Coins. The types commonly consist of the Temples of the Deities in the respective Cities, which, from their great variety, are not deficient in interest. The Legends, as we stated, are in Greek, and often literally translated from the Roman; as ΑΥΤΟΚΡΑΤΟΡ, for Emperor; ΣΕΒΑΣΤΟΣ, Augustus; ΚΑΙΣΑΡ, Cæsar, &c. Among the Legends peculiar to this class, we may mention the names of Magistrates, and the title ΝΕΩΚΟΡΟΣ, applied to certain Cities, implying their appointment to the guardianship of the shrine of some celebrated Deity: a distinction much coveted, as the Temples greatly contributed to the wealth and importance of many States. As these Coins, not only of the chief Cities, but also of many Towns of inferior note, are abundant, and as the Provinces at that time included nearly all the civilized parts of the Globe, their number is almost infinite: they commence in the reign of the Emperor Augustus, and terminate with that of Gallienus, about 250 A. D. As an enumeration of the Cities which struck Coins would occupy too much space, and, moreover, be devoid of interest, we shall specify the most considerable of the Provinces in which they occur. Proceeding in an Easterly direction, we arrive at Mæsia, Thrace, and Macedonia, where they are of common occurrence; a few are to be met of Cities in the Peloponnesus, the Islands of the Ægean Sea, and those adjoining the Ionian coast. Of the Cities of Asia Minor they are found in great abundance; in the district of Phrygia no fewer than fifty Cities obtained the privilege of striking Coins; in Lydia they have been found of about thirty Cities; in Cilicia twenty and; so on of the other Provinces, Bithynia, Cappadocia, Pamphylia, Galatia, &c. Imperial Greek Coins are common of many Cities of Phœnicia, at that period divided into Commagene, Palestine, and Cœle-Syria. These Coins are chiefly of copper, the silver which exist being confined to the leading Cities, as Antioch, Tarsus, Tyre, Sidon, &c.

Grecian
Imperial
Coins.

Imperial
Coins of the
City of
Alexandria.

The Greek Coins of the City of Alexandria, struck in the Imperial Age, from their number and extent, (they reach to Constantine,) have a distinct place allotted to them in a Cabinet. In their fabric they are greatly inferior to the Roman Coins; and those of Copper are thick and uncouth in their form, with the characters at times barely legible. The symbols are slightly varied from those of the preceding class, by the introduction of numerous devices characteristic of the Country; as heads of Jupiter Ammon, Isis, and the God Canopus; also animals of worship and plants,—among the former, the sphinx and serpent prevail, and among the latter, the lotus and wheat-ear.

Colonial
Coins.

Coins of the Colonies, like those of the Provinces, extend to the reign of Gallienus; this form of government prevailed chiefly in the Augustan Age, but the number of the Cities is inconsiderable. Spain is the chief repository for the Colonial Coins, and those of the *Municipia* or Free Cities, governed by their own laws; in that Country there are found Coins of about thirty Colonies, all of which were planted in the reign of Augustus. As few of the Cities were permitted by succeeding Emperors to strike their Coins, and as the privilege was altogether denied them by Caligula, the pieces are not many in number; they abound chiefly of the Cities Carthago Nova, afterwards Carthagena, Cæsarea Augusta, corrupted into Saragossa, Bilbilis, Turiaso, and Emerita, the present Merida. The remaining Colonies whose Coins remain, were scattered throughout the Empire, and are as follows: Nemausus, in Gaul, (the only Colony permitted to strike silver Coins,) Panormus, Carthage, and Corinth; Philippi and Pella, in Macedonia; Parium, Alexandria, Troas, and Iconium, in Asia Minor; Tyre and Sidon; Ptolemais, Cæsarea, and Damascus; also a few Cities in the territory of Edessa. The type affixed to the early Colonial Coins, was that of a team of oxen, and subsequently banners appear; of these it may be remarked, that when standing alone they signify the Colony to be drawn from one Legion; but where several are introduced, they indicate the Colony to have been drawn from as many Legions as there are banners.

III. Medallions.

Medallions are all that remain to be noticed among the Imperial Coins; they were struck both at Rome and in the Provinces, and hence are divided into Roman and Grecian. The term Medallion is applied to those productions of the Mint which, in gold, exceed the size of the *Aureus*, in silver, of the *Denarius*, and in copper, of the first or large brass. Doubts have long prevailed among antiquaries as to the purposes for which they were designed; they are generally conceived to have been struck upon similar occasions to those on which Medals are coined among ourselves; upon an accession to the throne, in commemoration of any important victory, or as specimens of workmanship. There are, however, a few circumstances which favour the supposition that they were intended for circulation as money. Pinkerton speaks of gold Medallions being found equivalent in weight to two, three, and sometimes four *Aurei;* also some in silver to a like number of *Denarii;* thus making them analogous to the Greek *Tetradrachmæ.* The smallness of the number of existing Medallions by no means weakens this supposition; as at the present day the Two-guinea pieces, silver Crowns, and copper Twopenny pieces are by no means common, and might in a future Age, with equal propriety, rank as Medals. Medallions are at all times accounted rare, but those struck in the Grecian territories are the most numerous, and are distinguished from the Roman by their thinness and inferiority of workmanship. A gold Medallion exists of Augustus Cæsar and one also of Domitian, but few in any of the metals appear prior to the reigns of Hadrian and Antoninus; those in brass are considerably the largest, many of them being several inches in diameter. The Provinces in which they chiefly abound, particularly those of silver, are Asia Minor and Syria, including the opulent Cities of Ephesus, Smyrna, Thyatira, Pergamus, Cyzicus, Magnesia, Cæsarea, Sardis, Antioch, Tyre, Sidon, &c.

Value of Roman Imperial Coins.

As in a former section we detailed the value and denominations of the Roman Coins down to the Augustan Age, there remains but little to be noticed under this head. For the period of two centuries the Coins bore nearly the same value as at the close of the Commonwealth, experiencing, however, a gradual diminution in their sizes; but at the decline of the Empire, from the leading Coin being so materially reduced in size, it was found necessary, from time to time, to issue pieces of greater value. The amendment of the Coinage engaged the attention of many Emperors, but our knowledge on the subject is very confined. The confusion of sizes, occasioned by the new Coinage, prevailed to such an extent as to render it impossible, upon reference to the Coins, to point out the denominations specified by Historians; the results indeed are so unsatisfactory that we shall merely offer some few remarks, which will enable us to trace the changes which the chief Coins in each metal underwent.

Brass and copper.

Since the brass Coinage is that of chief importance, we commence with the *Sestertius.* This Coin, the reader will recall to mind, was equivalent in value to four *Assaria* and two *Dupondii;* and that four of them were included in the *Denarius.* The copper Coins being found of several sizes, are distinguished into first, second, and third brass. The first, or large brass, includes the *Sestertius;* this Coin appears about the reign of Augustus, and extends without intermission to that of Postumus. In the reign of Alexander Severus it had sustained a loss of one-sixth in weight; with Trajanus Decius it was reduced to one-half, and finally it did not exceed a third of its original size. The second, or middle brass as it is termed, approximates in size to our Halfpenny, and includes the *Dupondii* and *Assaria.* The *Dupondius* accompanies the *Sestertius* in the several stages of its decline, and closes together with it; the *As*, also, at that period, did not exceed the size of the early *Denarius*, and, together with its parts, was numbered with the third brass. The third, or small brass, comprises all the parts of the *As*, and consequently admits of great diversity in size. The *Dupondii* and *Assaria* were of equal dimensions though differing in their value, the latter being but one-half of the former; this circumstance is thus explained. In a former page we noticed that brass was highly esteemed at Rome, much more so than copper, it is therefore conceived that, as Imperial Coins of the middle size exist in both metals, brass was used for coining the *Dupondii*, and copper for the *Assaria.* Pinkerton states that the *Sestertii* and *Dupondii* were of brass, and the *As* and its parts of copper, a metal but half the value of the former. This ingenious explanation is correct in many points, but we cannot agree with the author in considering it as conclusive; for upon examining the Coins in question, we frequently meet with *Sestertii* unquestionably of copper; neither are there sufficient grounds for pronouncing all of the second size existing in brass to be the *Dupondii* mentioned by Pliny and other writers. Under the reign of the Emperor Gallienus, the chief copper Coins were the *Assaria;* these, from their diminished size, came to be numbered at sixty to the *Denarius*, and in the Age of Constantine they scarcely exceeded twenty grains in weight. With the Emperor Diocletian a new Coin appeared, denominated the *Follis;* this remained the chief copper Coin under the Lower Empire, and from the writers of that Age we learn that it was variously subdivided. The types of the reverses consisted simply of Greek characters, supposed to express the number of *Noumia* (the smallest copper Coin then in circulation) which they contained; thus the *Follis* bore the letter M, to denote forty *Noumia*, its half K for twenty, and the quarter I for ten. Our knowledge, however, of these Coins is too imperfect to admit of our placing any great reliance upon this computation.

Value of Roman Imperial Coins.

Plate II Fig. 1. 3.

Fig. 5.

Fig. 4. 7. Silver.

The silver Coins in the Age of Augustus were of two kinds, the *Denarius*, containing sixteen *Assaria*, and the *Quinarius*, or its half; these pieces gradually decreased, and in the reign of Caracalla were struck of two sizes; the new Coin was denominated *Argenteus*, and raised in value to one-third of the current *Denarius*, containing consequently twenty-four *Asses*, or *Assaria.* The common *Denarius*, which now went by the name of *Minutus*, ceased to be struck in the reign of Gallienus, the *Argenteus* supplying its place; the terms *Argenteus* and *Denarius* were then but different names for the same Coin, which at that time contained the surprising number of sixty *Assaria.*

Constantine the Great effected a material alteration

Numis-
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in the silver Coinage, by the introduction of the *Milliarensis*, which he caused to pass for twenty-four *Folles*. *Denarii* were struck so late as the reign of Heraclius, when they did not exceed ten grains in weight; upon the first appearance of that Coin (the parent of our silver Penny) it exceeded ninety grains in weight, and under Augustus it had fallen to sixty grains at a medium.

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The *Aureus*, the chief gold Coin under the Commonwealth, and the *Semi-aureus* constituted the sole pieces in gold for nearly three centuries; at the expiration of that period, *Aurei* were struck of several sizes, and new Coins issued of one-third and of double their weight; the former being denominated *Trientes*. Until the reign of Alexander Severus, the *Aureus* passed current for twenty-five silver *Denarii;* the weight originally given to this Coin was about 120 grains; it now fluctuated between eighty and ninety grains. Constantine the Great accommodated the *Aureus* to his new silver Coinage, and gave it the name of *Solidus;* this piece remained the chief gold Coin until the fall of the Eastern Empire, and for a time *Semisses* and *Tremisses* were struck. The *Semi-aureus* of gold is at all times a very scarce Coin, but was more especially so under the reigns of the early Emperors.

The following Table of Roman Coinage exhibits the weights and value, as established about the Age of Augustus:

Teruncius. *Quadrans.*									*Weight.* oz.	*Value.* £.	s.	d.
2	Sembella *Semis.*								0⅛	0	0	0¼
4	2	As or Libella *Assarium.*							0¼	0	0	0½
8	4	2	Dupondius						0½	0	0	1
16	8	4	2	Sestertius *Nummus.*					1	0	0	2
32	16	8	4	2	Quinarius *Victoriatus.*				grs. 30	0	0	4
64	32	16	8	4	2	Denarius			60	0	0	8
960	480	240	120	60	30	15	Semissis (15 Denarii) *Semi-aureus.*			0	10	0
1920	960	480	240	120	60	30	2	Aureus (30 Denarii)		1	0	0

3d Brass.* 2d Brass. 1st Brass.

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lCoins.

Before quitting the Roman Coins, we shall, in accordance with our plan, consider the light in which they are to be regarded as works of ancient Art. The inspection of the Imperial Coins will, we feel confident, be productive of the highest satisfaction; but we must bear in mind that Rome herself in works of Art cannot sustain competition with Greece. The period at which the Roman Coins stand preeminent for the excellency of their workmanship, may be placed in the Age of the Antonini. We mentioned that patronage was extended to the Arts by Augustus Cæsar, as may indeed be inferred from his Coins; (especially those in gold and silver;) no material improvement is evinced in the Coinage under the reign of his immediate successors, probably owing to the turbulent state of the times; but a superiority is decidedly manifested as we descend to the reigns of Vespasian and Titus, after which period they gradually increase in beauty of fabric, until they attain their greatest excellence at the epoch above-named. We may date the decline of the Art as commencing about the Age of Commodus; there are, it is true, instances of Coins, in the century which succeeded, rivalling in their execution those of the best Ages of the Empire, but they are of rare ocurrence. For the fifty years antecedent to the extinction of the Western Empire, the Coins are of the worst possible fabric, equalling, in the barbarism of their workmanship, those of the Dark Ages; and, indeed, the Coinage of the Princes who immediately preceded is but little superior.

Workman-
ship of
Roman Im-
perial Coins.

Portraits on
Roman
Coins.

No fewer than three hundred portraits are preserved in the series of Roman Imperial Coins; for not only are the Emperors depicted, but also the Empresses and the several branches of the Imperial family. Among the many examples which might be adduced, we select those of Augustus and Trajan. Independently of the Coins of Augustus, we meet with those of his Empress Livia, of their daughter Julia, and son-in-law Agrippa; a few also occur of the grandsons of the Emperor, namely Caius and Lucius Cæsar. Besides the Coins of Trajan we meet with those of his father Trajan, of his Empress Plotina, of her sister Marciana, and niece Matidia. The Roman Emperors commonly appear either with radiated or laurel crowns, but never with the diadem, as the Greek Princes. In a late period of the Empire, helmets were introduced, and the bust of the Emperor was clothed in armour. Endless variety prevails in the head-dresses of the Empresses.

An opinion, we believe, has gained ground, that no reliance can be placed upon the representations handed down to us in these minor productions of ancient Art; we can only account for the prevalence of this notion from the portraits occasionally to be found in Historical Works, and presumed to be accurate delineations of the Coins. It must be confessed that far the greater number of those which have appeared in Numismatic Works, in which at least accuracy would be looked for, are entirely disgraceful to them. The heads of the twelve Cæsars are of common occurrence, both in the form of engraved plates and of casts; these, we admit, do generally retain the distinguishing features of the Emperors, but upon comparing them with the Coins, they will be found to fall considerably short of that marked expression, that admirable discrimination of character, prevalent throughout the series. Among the instances which might be adduced in favour of strength of resemblance, we may mention the perfect accordance in character of the Coins, however numerous, of the same Prince during the better Ages of the Empire; and again, the perfect agreement of these with the remaining busts of these Emperors; and here, in passing, an instance of the practical utility of the study of Numismatics presents itself. Marbles frequently exist without any inscription which can inform us for whom they were designed: Coins, on the other hand, being invariably accompanied by a Legend, have effectually enabled antiquaries to adjudge the heads to their respective Emperors. One more observation will close our remarks on the portraiture. Were the Legend of an Imperial Coin totally obliterated, and only the head entire, but a little knowledge of Coins will enable the student to pronounce for whom it was designed; and we will venture to say that the inspection of a

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* The minor divisions of the As were sometimes struck.

Coin would be attended with a similar result, in the hands of a skilful Medallist, if not only the Legend, but a considerable portion of the head, were effaced.

Sect. III.—Coins of Barbarian Nations.

Barbarian Coins are those inscribed with characters differing from the Greek and Roman; there are, however, many Coins wholly destitute of Legends, and a few on which Roman characters appear, which, with great propriety, may be ranked among them. The following will be the order under which we shall consider them:

Asia.	Africa.	Europe.
Lydia. Persia. Judæa. Phœnicia.	Numidia and Mauritania. Carthage.	Etruria. Spain. Gaul. Britain.

Lydia.—We commence with this Country, being that in which pieces of metal were first stamped with symbols, and used as the representatives of property. The nature of the Lydian Coinage has been already described; it consisted of rude lumps of metal, deeply indented on one of the sides, by the puncheon on which the metal was placed in order to receive the impression. Plate II. Fig. 10. The symbols consisted of figures of men and animals, rudely executed, and many of the Coins are formed of the metal *Electrum*, a compound of gold and silver: they are totally destitute of characters.

Persia.—The Coins of this Country may be subdivided into three classes: the first extending from the reign of Darius to the Age of Alexander the Great; the second including a few which were struck from that Prince's reign until the full establishment of the Parthian Monarchy; and the last comprising the Coins of the Sassanidæ, successors to the Parthian Kings. I. The Coins of Darius, as we before remarked, may probably be referred to the Prince of the same name, sometimes called Astyages, a King of the Medes. On the reverses of these Coins, which are of gold, several rude indentations appear, without an approach to any regular form; Fig. 12. the Coins are generally of an oval shape, and bear for their type an Archer, attired in the Persian costume, and holding in his hand a bow: the scarcity of these pieces, which at one period must have abounded, was caused by their being recoined by succeeding Princes. The symbol of the Archer gave rise to a *bon mot*, related by Plutarch in his *Life of Agesilaus;* when that Prince was forced to retire from an invasion of Persia by the largesses which Artaxerxes distributed among the enemies of Sparta, the Spartans spread a report that he was defeated by thirty thousand archers. II. The second class comprises a considerable number of Coins, but they lose much of their interest from the great uncertainty which exists as to their date; they are found in all the metals, and class with the Persian, the greater number of their devices being characteristic in that nation; as, however, several of them bear the type of a vessel, and are moreover inscribed with Phœnician characters, there are grounds for believing them to have been struck by Phœnician Cities dependent on Persia. From our present imperfect knowledge of this class of Coins, and the prospect that ere long this uncertainty will, in some measure, be removed, (for they are now engaging the attention of some learned antiquaries,) we shall not hazard any further conjectures on them, but proceed to the third division. III. The race of Princes denominated Sassanidæ, came into possession of Parthia A. D. 226. That Kingdom was not entirely destroyed until the Age of Mohammed, but the Coins do not extend later than the IVth century; these are nearly all of silver, and materially differ in their character from any of the preceding; the relief of the object is inconsiderable, and the Coins are extremely thin; they possess, however, a correspondent increase in their diameter. The Legends are inscribed in the Persian Tongue, and the portraits of the Princes are rendered curious by the singularity of the costume, which is depicted with great care. The symbols of the reverses are of two kinds; the first consists simply of an Altar burning, (bearing an allusion to the invisible Deity of the Persians,) there being at that period no Temples, but only an altar kept constantly burning in the open air: this worship afterwards declined into that of the Sun and Fire. The second device was also an altar, on one side of which appears the Monarch, and on the other the Chief of the Magi. The finest Coins of the series were struck when the Kingdom was in its greatest power, and are remarkable for their neatness and high finishing; but after the lapse of a century or more they greatly decline in execution.

Judæa.—The Hebrew Coins were struck under the dominion of the Family of the Maccabees, and chiefly in the time of Simon, High Priest, 150 B. C. They are nearly all of copper, and invariably rude in their execution. The Legends are inscribed in Samaritan characters, and the symbols all of which are characteristic of the Nation, possess some variety; Plate II. Fig. 13. thus we have sprigs of plants, supposed to represent Aaron's rod, Temples, sacramental cups, censers, and tabernacles. Palm-branches and vine-leaves form also common devices.

Phœnicia.—Distinguished as were the Phœnicians at an early period for their commerce, they do not appear to have instituted a Coinage prior to the Age of Alexander the Great; weight being employed in lieu of it among them as well as the Carthaginians. The Coins of the Greek Cities in Phœnicia are not comprehended in this class, which comprises only those either without Legends or bearing Phœnician characters. Among the devices we may notice the turretted head of Cybele, and figures of Astarte, the Sidonian Goddess; the most common reverse is a vessel, as the emblem of commerce; palm-trees (φοίνικες) are also common, indeed they were so abundant in Phœnicia as, according to some writers, to have given name to the Country. The greater number of the above Coins have been referred to the Cities Tyre and Sidon.

Numidia and *Mauritania.*—Juba I. was King of both Countries, he espoused the cause of Pompey, and being defeated, put a period to his existence; his son Juba II. was educated at the Court of Augustus, and received from that Emperor the territory of Numidia. The series of Coins commences with Juba I., of whom they are numerous in silver, but little variety prevails in the devices, a Temple forming the common reverse. Many copper Coins likewise are ascribed to this Prince, but they are unaccompanied by his portrait. The symbols on the Coins of Juba II. are sometimes Roman and sometimes Numidian; among the former we may notice curule-chairs, cornucopiæ, and the sign Capricornus, taken from Coins of his protector Augustus. The Numidian symbols are the lion, elephant, and palm-tree, which are all found on the Coins of that Prince. Juba II. espoused an Egyptian Princess, Cleopatra, of whom likewise there are Coins, bearing for their types the sistrum and lotus plant.

Carthage.—The Punic Coins are frequently confounded with the Phœnician; they were probably struck at the time of the Ist Punic War, during which the Nation had attained its greatest power. The Carthaginians trafficked for many Ages in gold and silver, but they do not appear to have instituted a Coinage prior to the above period: indeed, it is uncertain whether a Mint was ever established at Carthage, and whether the money may not have been the produce of her Colonies. Many of these were planted on the coasts of Spain and Sicily; a few of the Coins struck in the last-named Island are deservedly admired for the beauty of their workmanship, but they were the fabrication of Greek artists. The Legends, when they appear, are in Phœnician characters, and the types of the reverses usually three in number; the most common is a horse, of which a head only is sometimes represented, at other times the forepart of the animal, but more frequently the entire figure: the type is said to have originated from a tradition that a horse's head was discovered in digging the foundations of the City. A palm-tree is another very common device, and is most frequently introduced in connection with the preceding; the tree was common to the rivers of Northern Africa, and may, in the present instance, have served to denote that the Carthaginians were of Phœnician extraction. Lastly, we may notice the lion, a symbol common to Numidia; the types on the obverses of those struck in Sicily consisted of heads of Ceres, the chief Goddess of the Island.

Spain.—This Country was divided by the Romans into Bætica, Tarraconensis, and Lusitania, the present Portugal; Bætica was peopled long before the rest, being advantageously situated for commerce. The Colonies first planted here were by the Phœnicians, and of these Gades, now Cadiz, was the most considerable; the Greeks next established themselves on the coast, but none of their Colonies rose to eminence: the Carthaginians succeeded to the Greeks, planting Carthago-Nova, the present Carthagena, and numerous other Colonies. The Coins, as we should expect, partake of the character of those of the several Nations by whom the Country was inhabited, and appear inscribed with Phœnician, Greek, and Roman Legends; a few also are to be met with bearing Celtic characters, being struck by a Tribe who settled in the interior of the Peninsula near the Iberus, and were thence denominated *Celtiberi*. The symbols common to Coins of these Cities, consist of a horse, from that animal abounding in the Country; ears of barley, emblematical of the fertility of the soil; (the South-Eastern portion;) an olive-branch, as olives were cultivated there in great abundance; and lastly, fish, appearing on Coins of the seaport towns. A few heads, likewise, appear on the Coins of Cities removed from the coast, and are chiefly those of Barbaric Chiefs and of Hercules: that Deity was especially honoured in Spain, it being the Country reported to have been traversed by the Hero, and that in which one of his Columns was planted.

Coins of Barbarian Nations.

Gaul.—The early Coins of this region are scarcely worthy of notice, indeed, little intercourse subsisted between it and the Southern Countries, prior to its reduction by Julius Cæsar. This Country became known to the Greeks by the establishment of the Colony Massilia, (now Marseilles,) which also gave rise to the formation of numerous Greek settlements along the coast: the Coins of these Cities can scarcely bear the name of Gallic, and have, in consequence, been classed with those of Greece. Gold, it would appear, was found in great abundance in many parts of the Country, and formed a chief article of commerce; the early Coins, struck about half a century or more before the Christian Era, are common in this metal, being in appearance rude lumps of gold, with types of such Barbarian workmanship as to be frequently unintelligible. The devices consist of heads of Chiefs, with their names inscribed in Roman characters; and of horsemen, or simply a horse running: the Gauls were noted for their skill in training these animals, which, moreover, abounded in the Country.

Britain.—Julius Cæsar, in his *Commentaries*, when noticing the manners and customs of the inhabitants of Britain, has stated, that they made use of iron rings of a prescribed weight for money, and that copper was coined as a superior metal:* their knowledge of the Art was probably derived from their intercourse with the Northern coasts of Gaul, as we find the Coins of both Countries frequently resemble each other. The first stamping of money in our Island is conjectured to have taken place at a period subsequent to the second invasion of Julius Cæsar;† and we afterwards meet with the Coins of a few Generals, to which succeed those of Cunobelin. On the Coins of that Prince much has been said and written; we do not, however, purpose entering upon the discussion, even if our limits permitted, since little information of a satisfactory nature is to be gained. Cunobelin reigned over a considerable extent of country lying to the North of the Thames, and inhabited by the *Trinobantes;* two Cities are stated as having been the Capitals of his vast Kingdom, Verulam, (St. Alban's,) the most ancient, and Camulodunum. (Colchester.) The reign of Cunobelin extended to the Age of Caligula. His Coins abound in all the metals, and are so diversified in their general character and types that they can with difficulty be ascribed to the reign of a single Prince. The portraits on the obverses differ materially from each other, and many of the devices are obviously taken from Roman Coins.

The ancient Coinage of Britain terminated with this Prince, for in the reign of Claudius, the Island was brought under complete subjection, and an edict passed, ordaining that all the Coins struck in it should be impressed with the effigy, name, &c. of the Emperor; whereupon Roman Mints were established in the chief Cities, and the Coins were numbered among those of the Empire. A horse and ears of barley form the most common devices on the Coins of Cunobelin, and for the Legends, besides the name of the Prince, we meet with the characters VER and CAMU, being the commencement of the names of the ancient Cities above specified.

Plate II. Fig. 14.

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* *De Bello Gallico*, v. 12.

† Ruding, *Annals of the Coinage of Britain, &c.*

PART II.—MODERN COINS.

Sect. I.—*Character of Modern Coins.*

Coins are rendered interesting chiefly from their devices, and, in proportion as these are diversified, so will they prove valuable documents to the Historian; the Legends next deserve notice, and we then proceed to examine their fabric, proportionate value, &c. First, then, as regards the symbols; these we have shown are of exceeding great variety both on the Grecian and Roman Coins; our limits have only admitted of a selection from among them, but there are many others equally worthy attention. They afford a considerable insight into the Heathen Mythology, portraying the Deities chiefly worshipped throughout the Grecian States, and the personifications in use with the Romans; they, also, not unfrequently, acquaint us with the manners and customs of the Nations to which they belong; the costume is carefully depicted, and a numerous and very complete series of portraits is preserved. If we now turn our attention to Modern Coins, the devices affixed to them, from the extinction of the Western Empire until the XIIth century, will be found to consist in little more than a cross; a device, it is true, diversified and ornamented after every possible manner, but from which no characteristic information can be acquired: it was a type adopted by the Eastern Emperors on their Coins to denote their conversion to Christianity, and afterwards used for a similar purpose by the Gothic Sovereigns. The Arms of a Country were introduced in conjunction with the cross in the XIIth century, when the latter symbol gradually fell into disuse; and the remaining devices, which from time to time appear, are, with but few exceptions, little connected with the varying History of Nations. The brevity and comprehensiveness of the Legends on Ancient Coins is well deserving of attention; no more words being introduced than are absolutely requisite to convey the intended meaning, while we are frequently surprised to find how much information is embodied in the few characters employed: diffuseness, on the other hand, is a leading defect with Modern Medals, if not with Coins; a confusion often existing between the Legend and the device, and a multitude of characters being employed to express a thought comparatively trifling. The Legends on the Coins of the Middle Ages are distinguished by the insertion of the names of the Mint-masters in connection with those of the Cities in which the Mints were established; for it will be proper to observe that all the towns of note, throughout the European Kingdoms, had their respective Mints; (in England they existed to the number of fifty or more;) over each of these a Mint-master or superintendent was appointed, who being responsible for the purity of the metal, &c., was under the necessity of inserting his name in the Legend.

Symbols on the Coins of the Middle Ages.

Legends.

In this division of our subject, we shall no longer take into consideration the proportionate value of the Coins; (those of our own Country excepted;) indeed, any attempt of the kind would be attended with considerable labour, and all interest would be destroyed, from the impracticability of tracing the various changes they underwent. Throughout the Middle Ages the silver Penny was the only Coin of importance, being struck upon the model of the Roman *Denarius;* very little gold was employed in the mintage, and the introduction of copper is of extremely recent date.

Metals employed.

The fabric of Modern Coins is as little deserving of notice as the other qualities we have named respecting them; and, omitting those of the last few centuries, they must be acknowledged to be greatly inferior in their workmanship to the Coins of the two great repositories of ancient Art, Greece and Rome.

Modern Coins prior to Charlemagne.

Portraits appear on Modern as well as Ancient Coins; but such was the state to which the Arts were reduced in the Dark Ages, that frequently no discrimination of character is apparent in the representations of the Princes handed down to us. The relief of the Coins is also inconsiderable, and the pieces are extremely thin; a peculiarity by no means consequent on the practice of employment of the hammer to obtain the impression, since a similar method was adopted by the Greeks and Romans, while their Coins are of quite an opposite character. The preceding remarks relate chiefly to Coins struck prior to the XVth century.

Workmanship of the Coins of the Dark Ages.

The Coins of the modern Asiatic Kingdoms are numerous, but as they materially differ from those of Europe, we think it desirable to consider them apart; they will, in consequence, close the present section.

Modern Coins of Asia.

It is difficult, if not impossible, to fix upon any precise era as forming the boundary of Ancient and Modern History; one period there must be in which the events will seem equally entitled to fall under either division. Of the several epochs named by Historians as terminating the annals of the Ancient World, there are two more especially deserving attention—the extinction of the Western Empire 476 A. D., and the Age of Charlemagne, crowned Emperor of Rome 800 A. D. We therefore purpose, in the first place, to take a short survey of the Coinage of the European Countries from the Vth century of the Christian Era to the death of Charlemagne.

Eras assigned for the commencement of Modern Coins.

Spain.—The Coins commence in this Country with Liuva, Prince of the Visigoths, A. D. 576, and are nearly complete of his successors, down to Roderic the Great, when the Gothic Monarchy became extinct in Spain. These Coins are chiefly in gold, and are found of two sizes, being struck upon the model of the *Trientes* and *Semisses* of the Lower Empire. The symbols consist of the heads of the Princes, executed in a most wretched style, and a variety of crosses; the latter device was taken from the Coins of the Lower Empire, and affixed in order to denote the conversion of the Princes to Christianity: in a few instances, portraits appear on both sides of the Coins. The characters on the Coins struck in the Dark Ages, and especially at this early period, are so mishapen, differ in many instances so materially from the present mode of representation, and are so erroneously placed, that the inspection of a considerable number is requisite before the Legends can be deciphered with facility. The reverses bearing the crosses above alluded to, have for their Legends the names of the Cities in which they were struck, followed generally by the word PIVS; an epithet applied in common to the Byzantine Emperors, and in this instance to be regarded as a continuation of the Legend on the obverse. The Cities whose names appear are Ispali, (Seville,) Emerita, (Merida,) Corduba, (Cordova,) Cæsarea Augusta, (Saragossa,) Toledo, and a few others in Andalusia and the Southern districts.

France.—The first series is that of the Merovingian Kings, and commences with Clovis 490 A. D.; this race became extinct with Pepin, the grandfather of Charlemagne. These Coins are of gold, they were struck upon the model of the Roman Coins, and in many respects resemble the preceding. The title *Dominus Noster*, expressed by the initials D. N., is frequently prefixed to the names of these Princes, as upon Roman Coins; a globe is also commonly annexed to the cross on the reverse, and enclosed within a circle. Among the chief towns, the names of which are inscribed in the Legends, we may notice Parisiis, (Paris,) Aurelian, (Orleans,) Colonia, (Cologne,) &c.; they are usually preceded by the characters CIV, abbreviated for *Civitas*.

Italy.—The Coins of this Country which we last described, were the series of Emperors closing with the deposition of Romulus Augustulus by the Heruli, 476 A. D. The Ostrgooths shortly after acquired the dominion of Italy; their Coins are preserved down to Teias, who was vanquished by Justinian, but they are of indifferent workmanship, and in many respects resemble the Coins of the late Emperors. On one of the sides, the name of the Prince, expressed by a monogram or at full length, is inserted, and enclosed by a laurel wreath; the other side bears a portrait of the reigning Emperor at Constantinople, to whom allegiance was acknowledged. Upon Italy being again annexed to the Empire, Viceroys were appointed by the Eastern Emperors, who fixed their seat at Ravenna, and issued Coins; they have, however, nothing remarkable to distinguish them. The Country afterwards fell under the power of the Lombards, and notwithstanding they maintained possession of it for nearly two centuries, no Coins of their Monarchs appear, those of the Eastern Empire probably sufficing.

Britain.—Roman Coins were current in our Island until the arrival of the Saxons and the formation of the Heptarchy: of the seven Kingdoms of which it was constituted, the Coins of five remain; namely, Kent, East Anglia, West Saxony, or Wessex, Mercia, and Northumbria. The Archbishops of York and Canterbury, likewise, exercised the privilege of Coining, and many of their pieces remain. The early Saxon Coins were the *Sceatta* and *Styca;* this last was of copper, very small in size, and its circulation confined to the Kingdom of Northumbria. The following is the order of the Kingdoms, and the names of the Princes with whom the Coins commence. Kent with Ethelbert, 561 A. D.; Northumbria, Ecgfrith, 670 A. D.; East Angles, Beonna, 690 A. D.; Mercia, Eadbald, 716 A. D.; and West Saxony, or Wessex, Beorhtric, 754 A. D. The *Sceattæ* were the earliest productions of the Mint, and are distinguished from the Penny by their being of inferior weight and dimensions. They were struck in the Pagan times, the crosses seldom appearing; birds formed the common symbols; we meet also with representations of Romulus and Remus, and sundry marks, probably designed for letters. Portraits of the Monarchs were subsequently introduced, when the device of the cross also appears on the reverses. The *Stycæ* are remarkable for being the only copper Coins struck in England before the reign of Elizabeth; they bear the type of a cross, contained within a circle, and the names of the Princes, Mint-masters, and chief Cities. Saxon Pennies appeared in the Kingdom of Kent 750 A. D., and are found of nearly all the Princes from that period; they offer a great variety in their types, the diversity being occasioned chiefly by the manner in which the characters are disposed; they are sometimes disposed in two or three rows, separated by transverse lines; at other times they fall within the compartments made by the cross, and the variety of forms assumed by this type are not without some degree of elegance. The title REX is annexed to the names of the Princes, and in the instances of Egbert, and a few other Kings, SAXONVM is added; the names of the Mint-masters are commonly succeeded by those of the towns in which the pieces were struck: the most considerable of which, at that period, were Canterbury, York, Durham, Bristol, Dover, and Leicester.

Coins of the Eastern Empire.

The whole of the North-Eastern parts of Europe were then possessed by wandering Tribes of Barbarians; the Coins of the Eastern Empire differ from the Roman Coins last mentioned only in their inferior workmanship, and in the poverty of the devices. A considerable number of these are of gold, that metal being common at Constantinople at the decline of the Empire; a very complete series of Coins of the Emperors may indeed be formed in this metal, while that in silver and copper is frequently defective.

Having taken this hasty sketch of Modern Coins down to the Age of Charlemagne, we shall proceed in the same order with the remaining series.

Modern Coins from the Age of Charlemagne.

Spain.—To the series of Coins of the Gothic Princes succeed those of the Arabians or Saracens, who possessed themselves of all the powerful Cities in the South, and after a short time fixed their seat of Empire at Cordova: their Coins will be noticed with those of the Asiatic Princes. At the close of the Xth century the Caliphat was split into a number of independent States, as Toledo, Seville, Murcia, Saragossa, &c., at which time the Coins of the Christian States, which gradually rose into power, commence. No Work having been published on the modern Spanish Coins, we are unable to offer any account of them.

France.—The French Monarchy is distinguished by three races of Princes: the first of these was the Merovingian, extending to Pepin, the Coins of which have been already described; to this succeeds the race of the Carlovingian Kings, so named from the Emperor Charlemagne. Coins of this race are to be found struck in all the Cities of importance throughout France, and strongly evince the state of barbarism which prevailed: the Kingdom had rapidly declined since the time of Clovis, it rose into power with Charlemagne, but fell to pieces under his weak posterity. Portraits seldom, if ever, appear on this series, which consists chiefly of silver Pennies; and in rudeness of fabric they exceed all other Coins of the same period. The names of the first two Princes occupy one side of their Coins, in separate lines, and in characters of the rudest class; the field of the reverse is occupied by the initials R. F. (*Rex Francorum.*) Coins of Charlemagne also occur, struck at Rome, and superior in fabric to the above; the letters contained in the name of the City are placed at each extremity of a cross in the field of the Coin, and encircled by the Legend CAROLVS IP: the monogram expresses the title Imperator.

Coins of Charlemagne.

At the close of the Xth century, Hugh Capet seized upon the crown, and commenced the third, or Capetian race. The Coins are now of improved execution, but from the sameness and poverty of the devices for some centuries, they merit little attention. The types consist almost solely of crosses, and the badge of France, the fleur-de-lis; this last device sometimes occupies the entire field; it is also commonly affixed to each of the extremities of the cross, and introduced upon every possible occasion. In the early part of the XIIIth century, the *Gros*, or Great-piece, (whence our *Groat*,) came into circulation, and was so named from its size when compared with the Penny; soon after, pieces of several denominations were issued, as the *Liard*, *Maille*, *Obole*, *Blanc*, *Teston*, &c.; and about A. D. 1300, Coins of gold were struck, appearing in the form of the *Florin*. The gold Coins are very numerous; those of frequent occurrence are the *Chaise*, *Lion*, and *Ecu à la Couronne*: each of them was named after the devices it bore. Our limits will not permit us to notice at greater length the Coinage of this Nation, as we are anxious to reserve as much space as possible for that of our own Country.

Germany.—The Coinage of this Country consists of that of many independent States, and commenced soon after the Age of Charlemagne; no Work of which we are aware has as yet appeared upon the subject. The series of the Emperors is believed to be complete, and the Coins of the powerful Cities seated on the Rhine are very numerous.

Lombardy.

Italy.—We shall take in their order the Coins of each great division of Italy, *viz.* Lombardy, the States of the Church, and Naples, in each of which they long consisted only of silver Pennies, bearing the type of a cross. Among the independent Lombard Cities of which Coins are preserved, we may mention Milan, Mantua, Pavia, Venice, Lucca, Florence, and Genoa. Without dwelling upon each separately, we shall briefly remark on their general character; the States which struck Coins soon after the Age of Charlemagne, inscribed them with the names of the Emperor of the West on the reverse, to whom nominally they owed allegiance; the name of the City appears crossing the field of the Coin. The devices differ from those on the other European Coins, by representations of the patron Saints; thus we have St. Ambrose for Milan, St. Mark for Venice, and on the Coins of Florence St. John the Baptist; the Coins of the City of Mantua, the birth-place of Virgil, bear the name of that Poet for the Legend. The Florins, so named from being struck at Florence in the middle of the XIIIth century, are remarkable for being the first gold issued in Europe after the extinction of the Western Empire; (that of France and Spain, during the Gothic Monarchy, excepted;) they bear for their device the flower of the lily, and were immediately imitated by other European Powers. They appeared in England in the reign of Edward III.

States of the Church.

In the Papal dominions, Hadrian I. was the earliest Pontiff who obtained leave from Charlemagne to coin money, and some of his pieces are preserved; few portraits are found until a late period, the names of the Popes and of the Emperors of the West constituting the Legends: they are also sometimes expressed by monograms, placed in the field of the Coin. On one of the sides we read for the Legend SCS (Sanctus) PETRVS, and the name of the city ROMA or the word PIVS in the centre; the letters forming these words are placed at the extremities of a cross, after the manner noticed above, in the Coins of Charlemagne struck at Rome. Such was the character of the Papal Coins until the close of the XIVth century, when a great change appears in the devices; these consisting of figures of the Popes, seated, in their robes, with the symbols of the cross-keys, surmounted by a mitre, for the reverse.

Modern Coins from Charlemagne.

Naples.

The territory of Naples was possessed, in the Age of Charlemagne, by the powerful Dukes of Beneventum, tributary to that Prince; a few of the Coins struck by them are to be met with in Cabinets, but they possess little interest. At the close of the IXth century, the Saracens from Africa rendered themselves masters of Sicily and Naples, of which they retained possession until expelled by the Normans. The Normans, the most distinguished of the Crusaders, commenced their sovereignty with Roger the Great, and in the XIIth century, being dispossessed of the Country, it was annexed to the Empire. A series of Coins exists of the Norman Princes; they are of copper, small in size, and bear the names of the Princes in Arabian characters: they are found in great numbers, but are generally uninteresting.

Coins of Alfred and Canute.

Britain.—The Coins of the British Princes are very complete, from the first chief Monarch Egbert until the Conquest, and they nearly resemble the last Coins which we noticed of this Country. During this period, the silver Penny continued the sole Coin, the cross the ordinary type, and the names of the Monneyers, or Mint-masters, and of the Towns forming the Legends. On the Coins of Alfred are rude attempts at his portrait; the reverses of a few of them are curious; those which were struck at London have frequently for the device a monogram of that City. Under the reign of Canute, the Mints were more numerous than at any former or subsequent period; his head appears on the obverse of his Coins, crowned, and enclosed by a circle, constituted of four arches; the following is the Legend, ✠ CNVT REX ANGLORVM. The cross still forms the type of the reverses, and some idea may be formed of the number of modifications of which it is susceptible, when we mention that on the Coins of Edward the Confessor only no fewer than 500 varieties occur.

Denmark, Sweden, Russia, &c.—These Countries, forming the whole of the North-Eastern part of Europe, were parted off in numerous Duchies long before and after Charlemagne. Bohemia and Poland also were governed by Dukes from the Xth century, and Coins of both Countries remain. As few of these Nations are distinguished in History until a late period, the Coinage is generally of recent date; it was formed upon the model of that of the other European States, and therefore will not need a particular account. Crosses were sometimes placed on both sides of the Coins, and frequently the initial of the name of the Prince occupies the area of the obverse. About the XIIIth century the Arms of the Countries were adopted for the symbols, at which time also pieces of several denominations were struck.

Eastern Empire.—Coins are preserved of all the Princes down to the extinction of the Empire, but towards its close, the execution is of the very worst class. The devices, as we might suppose, are more varied in this series of Coins than in that of any other Country; among them we observe the cross, figures of Victory, representations of our Saviour, and of the Virgin and Child; the reverses are frequently occupied by inscriptions.

Coins of the Asiatic Kingdoms.

The most remarkable difference between Asiatic and European Coins consists in both the obverse and reverse being occupied by characters. The practice of placing inscriptions on the Coins, took its rise from the precept of Mohammed forbidding the representation of any living creature.

Arabia.—The Arabian Caliphs are distinguished into two races; the first of these, the Ommiades, succeeded the Persian Kings, the Sassanidæ, and fixed their seat at Damascus; the second, the Abassidæ, resided at Bagdat. The Coins commence with the third or fourth Prince of the first race, and are brought down to the extinction of the Caliphat; the characters are in the Arabic Tongue, and the symbols, if the sentences may be so termed, are of three kinds: the first, a passage from the Koran, declaring the Unity of the Godhead; the second declaring the Divine mission of the Prophet; and the last, consisting of parts of the two preceding. These sentences are variously disposed on the Coins, but generally the first two occupy the area on one of the sides, while round, and constituting the Legend, the name of the city (Damascus or Bagdat) and the year in which the piece was struck are inserted. The other side is chiefly occupied by the names and titles of the Caliph. The Coins of the Arabian Caliphs who reigned in Spain partake of the same character as the above, and were struck either at Cordova or Seville.

Asia Minor.—The Turks were the first Nation of importance who acquired an increase of dominion upon the decline of the Caliphat; they are distinguished into three powerful races: one of these resided at Ispahan, holding in tutelage the Caliphs of Bagdat; a second fixed themselves in the South-Eastern parts of Persia; and the third and most powerful, was a Tribe denominated the Seljuk Turks, who established their seat at Iconium, in Asia Minor, and subsequently removed to Nicæa, in Bithynia. Very few Coins remain of the former two races; of the third, however, there are many extant; on these the characters are disposed in the form of a square, and the passages from the Koran are omitted: the Legends consist of the names of the Prince, the places in which the Coins were struck, and the year. A symbol common to the Coins of one of the Princes is a representation of the Sun in the constellation Leo, which is remarkable as it constitutes the present Arms of Persia. The prevalence of Judicial Astrology at the period may have occasioned the introduction of the device, the Sign being probably that under which the Sultan was born: the Legend accompanying this type is the name of the Arabian Caliph resident at Bagdat, to whom these Princes nominally owed allegiance.

Egypt.—While the Saracens were declining in power in the East, the Egyptians rendered themselves independent, and were governed by a race of Princes, denominated the Fatimite Caliphs, until the conquest of the Country and its incorporation with Syria by the great Saladin. On the Coins of these Princes the characters are disposed in a triple range of concentric circles, and the spaces thus formed are occupied by the second and third symbols, as on Arabian Coins, a passage in praise of Ali, the successor of Mohammed, the titles of the Caliph, a sentence containing an exhortation to a belief in the Unity of the Godhead, the name of the Prince, the City in which the Coin was struck, and the year. The above Coins are of gold; a few exist of the Ayubite dynasty, also founded by Saladin.

The irruption of the Mogul Tartars in the XIIth century subverted the Caliphat of Bagdat, the Ayubite dynasty, and partially that of the Seljuk Turks. Of the Sufi, or Persian race of Kings, a series of Coins remains, extending down to a late period.

India.—The series most complete are that of the Sultans of Hindùstan, who fixed their seat at Delhi, and superseded the ancient Hindù Government, and also that of the Princes appointed by them, who reigned for two centuries at Bengal.

Turkey.—The Ottoman Turks issued Coins; but omitting those of the last century, they are rude and uninteresting, generally of a very small size, and contain only the names of the Princes, and the dates.

China.—A few of the Coins of this remarkable Nation may be traced as far back as the commencement of the VIIIth century; they are of copper, and are found but of two or three sizes. A perforation appears in the centre to facilitate stringing them, and until the XVIIth century, no device or inscription is seen on the reverses; on the other side various Chinese characters surround the square aperture, containing the titles of the Emperor, the place of Mintage, and words implying current Coin.

Sect. II.—English Coinage.

Perfection of the English series.

The Modern Coins of England are not of a kind calculated to throw much light upon its History, but they are entitled to distinction as being the most complete modern series extant. France ranks after England in the perfection of its series; it is, however, deficient in that of many Kings, whereas with us the Coins but of two Princes since the Conquest are wanting, Richard I. and John; of the former, however, some exist struck in France, and of the latter some in Ireland.

Early method of Coining.

The Coins struck prior to the reign of Charles II. are denominated "hammered money," from their devices being impressed by blows of a hammer; and this simple form during the early period of our History will account for the great number of Mints which existed. The process of Coining with the hammer was as follows: the metal after being melted, and the requisite alloy given for the purpose of hardening it, was beaten on anvils into large square plates down to the required thickness; these plates were next cut into narrow slips, and afterwards into small squares, when the operation of shaping commenced; this consisted in removing the corners with scissors, and by means of a hammer approximating them to a circular form. The pieces were afterwards weighed, those which were found to exceed the standard were filed, and in this state they obtained the appellation of *planchets*, and were ready to receive the impression. The dies were engraved upon two puncheons, one of which was stationary and received the planchet, while the other being held above it, the impression was effected sometimes at a single blow of the hammer.

Introduction of the mill.

Recourse was first had to the power of the screw for the purposes of Coining, about the middle of the XVIth century, and it was introduced by Antoine Brucher during the reign of Henry II. of France. It was used in that Kingdom for about thirty years, but from the expense attending it, compared with the former method, it was laid aside. The screw-press was not again resorted to until the year 1645, when by an edict of Louis XIV. its use was finally established: its revival at that period may be ascribed to the great number of Medals struck under that Prince's reign; for although it had been discontinued for the current Coin, it had always been resorted to for the Medals. The mill, or screw-press was introduced into England by a Frenchman, in the reign of Elizabeth, and employed in our

Mint for about ten years; at a subsequent period, Briot, an ingenious French artist, unable to prevail upon his Government to revive the use of it, came to England, and was favourably received. His machine was occasionally employed during the Commonwealth, but not for a continuance until the reign of Charles II. Briot, appointed chief engraver to the Mint, was succeeded in that office by Thomas Simon, an artist of great talent and ingenuity, who has left many admirable specimens of die-engraving. The operations of the Mint were now conducted on a very superior scale. The devices were, for the first time, engraved in relief on the puncheons, and stamped upon pieces of metal prepared for the purpose; these were termed *matrices*, and, in fact, constituted the dies. This method was adopted to counteract the delays occasioned by the breaking of the dies, owing to the pressure they received; as by means of the puncheon they could be renewed at pleasure. The metal after being melted was cast into bars of two or three inches in breadth, and the thin plates were obtained by the bars passing through the *laminating* or *flattening mill*. This machine consists of a pair of iron rollers, of considerable magnitude, which are kept revolving; as the bars pass through these, the metal becomes expanded in every direction, and by a succession of these machines, varying in their size, it is reduced to the required thickness. The plates of metal furnished by this operation are next taken to the *cutting-out press*; the chief feature in this machine is a species of steel trepan, adjusted to the dimensions of the Coins, by which thus the planchets are formed. After the pieces of metal are cleaned and weighed, nothing further remains but to affix the impression. In order to counteract the fraudulent practice of filing and clipping, Thomas Simon introduced letters on the edges of the large silver Coins, as the Crown and Half-crown, as may be seen to this day on the former piece. The instrument by which this was effected is very ingenious in its construction, and so simple in its operation as to throw off the Coins at the rate of sixty and seventy per minute. Graining succeeded to lettering the edges, and is at the present day effected at the same instant with the impression; the inner surface of the collar which receives the planchet being prepared for the purpose. The advantages possessed by the screw-press consist in the increase of power; so that the impression is obtained at a single blow, and much time consequently saved, also, as one firm and uniform pressure is given to the die, the most delicate strokes can be brought out: one defect yet remained, that of the machine being put in motion by human strength, and this in later years has been remedied by the substitution of steam.

Lettering on the edges.

The silver Coinage of England.

We commence with the silver Coinage of England, as being the most ancient; and for the sake of perspicuity we shall, for each metal, give the names of those Princes only under whose reigns any new piece was introduced, or any material alteration brought about in that which was then current.

William I.—The *Silver Penny* was a Coin well known throughout the Middle Ages, during which, as we have before stated, it was (with one or two exceptions) the sole piece. These Coins were struck upon the model of the Roman *Denarius*, and they now constitute the most lengthened sequence, ancient or modern, known; they commence with Egbert, and having been struck in the last reign, the series extends for upwards of a thousand years.

Plate II. Fig. 15

The Coins of William I. or II., for they cannot be distinguished, resemble in their devices and fabric those immediately preceding the Conquest; thus they offer rude attempts at the portraits of the Kings for the types of the obverse, accompanied by the Legend PILLELM REX, and on the reverse an almost endless variety of crosses, encircled by the names of the Mint-masters and chief towns.

Fig. 17.

Henry III.—The device of the Penny was slightly varied during this reign; hitherto the portrait of the Monarch had been commonly represented in profile, for which the full face was now substituted. The crosses on the reverse had, as we have before remarked, been greatly diversified, and were contained within a circle; they were now formed of double lines extending to the margin of the Coin, also in each angle of the cross pellets were inserted, but whether for any express object, or merely dictated by fancy, is unknown. The device of the cross, terminating in the circumference of the Coin, and dividing its area into four equal parts, prevailed until the reign of Charles II. On a few Coins of this Prince the Roman numerals III. are placed after the name.

Edward I.—The Coins introduced during this reign were the *Halfpenny* and *Farthing*, precisely resembling the Penny in their devices; the former were coined down to the reign of Charles I., and the Farthings so late as that of Mary, though scarcely of one quarter their original size, from the decreasing value of silver. The divisions on the surface of the Pennies formed by the arms of the cross, occasioned their being separated into halves and quarters, and in this state they were circulated in common with the new pieces. In Ireland there were Half-pennies struck as early as the reign of King John; they represent, as do also the Pennies, the head of the Prince enclosed within a triangle.

Fig. 21.

Edward III.—The *Groat* now made its appearance, taking its name from the French *Gros*, a large piece, and was valued at four Silver Pennies; the *Half-groat* was also struck. The Legends of this new piece differ from those on the preceding Coins; the obverse exhibits a full face of the Monarch crowned and enclosed by a circle formed of nine arches, the points of union terminating in the fleur-de-lis. The reverse bears the name of the City, (commonly that of London,) those of the Mint-masters being discontinued under Edward I.; around the margin is the sentence POSVI DEUM ADJVTOREM MEVM, inscribed on Coins so late as the reign of Edward VI.

Heraldic bearings first introduced. Fig. 22.

Henry VII.—It was under this reign that the *Testoon* or *Shilling*, valued at twelve pence, was first struck: the former appellation was taken from a French Coin, so named from its bearing the head (*teste*) of the Monarch. The word Tester is to this day employed in the North of England to designate the Shilling. The denomination Shilling is of uncertain origin; it was employed as a division of money in the period of the Saxon Heptarchy. The Royal arms were introduced on Coins for the first time in this reign, the cross dividing the escutcheon into four compartments. The obverse of the Shilling represented the head of the King in profile, crowned, and encircled by the Legend HENRIC. VII. DI. GRA. REX. ANGL. Z. H. (*et Hiberniæ*:) this is the first instance that occurs since the reign of Henry III. of Roman numerals appearing on English Coins, and their omission in the intervening reigns, particularly those of the Edwards, frequently renders it impossible to ascertain to which of the Princes they belong.

Henry VIII.—On the Farthings of Henry VIII. a portcullis appears, to distinguish them from the Halfpenny, as from their diminutive size they were frequently confounded: the Shilling also of this Prince differs from that of his predecessor, by the emblem of a double rose surmounted by a crown. Our Kings had up to this period styled themselves, on their Coins, "Lords of Ireland;" Henry VIII. first assumed the title of King of that Country.

Edward VI.—Several important additions were made to the silver Coinage in the reign of this Prince, the most considerable of which were the *Crown* and *Half-crown*, named after some Coins struck on the Continent, which bore for their device a crown. The type on the obverse of the Crown piece represented the King on horseback completely armed, and the horse richly caparisoned; the Legends and type of the reverse resembled those of the Shilling. The Half-crown also bore the type of the King on horseback,—a symbol which was retained so late as the reign of Charles I., when portraits of the Sovereigns were substituted. The remaining new Coins struck in this reign were the *Sixpence* and *Threepence*, on each of which the devices of the Shilling were repeated. The Roman numeral XII. and VI. were also impressed on the obverses to denote their value. In this reign the ordinary escutcheon divided by the cross, gave way for one of an oval form, richly garnished, and bearing the quartered arms of France and England; the device was accompanied by the Legend TIMOR DOMINI FONS EST VITÆ.

late II.
ig. 18.

Elizabeth.—Two minor divisions of the silver Money were introduced by this Queen; namely, *Three-halfpenny* and *Three-farthing* pieces: as, however, they could be dispensed with, and tended only to breed a confusion with the smaller denominations, they soon disappeared.

Charles I.—A few silver Coins were struck in this reign, and denominated, from their value, *Twenty-shilling* and *Ten-shilling* pieces; they were, however, soon called in, probably being inconvenient from their great size: the devices on these new pieces nearly resembled those of the Crown.

Commonwealth.—A new type appears on the Crown of the Commonwealth and of Cromwell, accompanied by an English Legend; they are generally of indifferent execution, and represent on one side St. George's cross in a shield between a palm and a laurel branch, and for the Legend, THE COMMONWEALTH OF ENGLAND. On the other side the above cross is repeated, accompanied by a second shield containing the harp; the device being designed to express the union of England and Ireland: the sentence GOD WITH US forms the Legend.

Charles II.—The devices on the Crown of the Commonwealth were discontinued at the Restoration, and a new variety introduced consisting of four escutcheons with the arms of England, France, and Ireland: this type finally gave place to that of St. George. The Legend DECUS ET TUTAMEN, on the edge, was introduced during this reign.

Soon after the reign of Elizabeth, the escutcheon was affixed on the reverses of all the small Coins from the Groat downwards, and subsequently gave way to the admission of ciphers. The Pennies of Charles II. bear the initial of his name; two of them appear with the Twopenny piece, three with the Threepenny, and so on. The Groats of this Prince contain the four ciphers, surmounted by crowns, and the badges of the respective Countries, the rose, fleur de lis, harp, and thistle inserted between them. On the small silver Coins of James II., Roman numerals express the value, and with William III. the modern figures.

The gold Coinage of England.

Henry III.—A Coinage of gold was instituted in the reign of this Prince, but from the few pieces which were struck, the introduction of the metal in our Mint is commonly referred by antiquaries to the reign of Edward III. The Coins of Henry III., alluded to above, were denominated *Gold Pennies;* probably from their accordance in size with silver Coins of that name, which they also perfectly resembled in the device of the reverse. But two of these Coins are at present known to exist. Their current value was 1*s.* 8*d.*, but this forming no part of the larger denominations, they were soon called in: the want, indeed, of a gold Coinage could have been but little felt at the time, as a term of ninety years elapsed before the metal was again resorted to.

Edward III.—The reign of this Prince forms a remarkable era in the History of our money. We noticed the Groat, in the silver Coinage, as having come into circulation with this Monarch, and we shall presently have to speak of the introduction of the *Noble*, one of the most remarkable of our gold Coins: our first attention is, however, due to the Florin. The *Florin* was first coined in England in the year 1344, and was accompanied by its *Half* and *Quarter.* This piece was issued in imitation of the gold Coins struck at Florence; none have yet been found, but two or three Quarter-florins are preserved in Cabinets, and the Half-florin was discovered a few years since. The symbol on the obverse is a lion, two of which it is said were affixed to the Florin. Crosses richly ornamented form the types of the reverses. The Florin was ordered to pass for 6*s.*, but from being overrated in proportion to the silver Coins, it ceased in a short time to be struck. The *Noble* was issued, together with its *Half* and *Quarter*, in the same year as the Florin, and is said to have taken its name from the purity or nobility of the metal: it was valued at 6*s.* 8*d.*, and its parts in proportion. The obverse of this Coin represents the King standing in a vessel, asserting the dominion of the sea; he bears in his right hand a sword, and in his left a shield, containing the quartered arms of France and England. This symbol is conceived to have been impressed on the Coins to commemorate a victory obtained by Edward over the French fleet. The Legend of the obverse is taken from the silver Coins. The reverse represents a cross richly ornamented; and in a small compartment in the centre, is the initial of the Prince's name. Each of the angular spaces formed by the cross is occupied by a lion surmounted by a crown, and the arms of the cross are terminated by fleurs-de-lis. The whole is contained within a circle formed of eight arches, with trefoils in the outer angles, and encompassed by the Legend IHESVS AVTEM TRANSIENS PER MEDIVM ILLORVM IBAT. This sentence, from the Gospel of St. Matthew, was worn as a charm or amulet, and considered as a preservative against the perils of war. The Noble ceased in the reign of Henry VIII. The reverses of those of Henry IV. differed from the preceding in bearing the type of an expanded rose as the badge of the House of Lancaster: this emblem gave rise to their being denominated *Rose-nobles.*

Plate II.
Fig. 16.

Henry VI.—The Noble was now raised to the value of 8*s.* 4*d.* and a new Coin introduced, namely, the

Plate II. Fig. 22.

Angel, valued at 6*s.* 8*d.*, the former value of the Noble, and hence it was denominated the *Noble Angel*. This new Coin received the appellation of Angel from the type of the obverse representing the Archangel St. Michael, with his left foot placed upon the dragon, which he pierces through the mouth with a spear. The reverse bears the type of a ship, partially resembling that of the Noble; a cross is substituted for the mast, and a shield, with the arms as before, is placed on the side of the vessel. The Legend is as follows, PER CRVCEM TVAM SALVA NOS XPE REDEMPT. The Angel extended to the reign of Charles I.; and shortly after its appearance, *Half-angels* or *Angelets* were issued, and circulated down to the reign of James I.

Henry VII.—The gold Coinage at this period of our History becomes perplexing, from the many alterations which the pieces underwent in value; the Noble, which in the time of Henry VI. had circulated at 8*s.* 4*d.*, now rose to 10*s.* and received the name of *Ryal*,—a word corrupted from *Royal*, the name given to a French Coin bearing the device of the King in his Royal robes. Henry VII. caused pieces of double the value of the Noble or Ryal to be struck, which from their device were denominated *Sovereigns*, and passed for twenty shillings. This *Double Ryal* is the parent of our present *Sovereign*, and was equal in size to the Crown-piece, but proportionably thin; on the obverse the King appears in his royal robes, seated on his throne, with the sceptre in his right hand, and the orb and cross in his left. A variety of ornaments are introduced too inconsiderable to be detailed. The reverse of the Sovereign represents an expanded double rose, to signify the union of the Houses of York and Lancaster; the central space is occupied by an escutcheon, and the Legend which encircles the device is similar to those on the silver Coins. The type of the double rose is given on Coins down to the reign of James I. Henry VII. also issued *Double Sovereigns*, differing only from the above in the increase of thickness; but very few were struck, on which account they are usually regarded as pattern pieces.

Fig. 19.

Henry VIII.—In the early part of this reign a greater variety prevailed in the gold Coinage than at any former or subsequent period. The pieces underwent likewise a material change in their value: the Noble was raised from 10*s.* to 11*s.* 3*d.*, and the Sovereign consequently was valued at £1. 2*s.* 6*d.*; the Angel, which had until now retained its value of 6*s.* 8*d.*, rose to 7*s.* 6*d.*; and a Coin was struck of the former value of the Angel, denominated the *George Noble*. The type of St. George overcoming the dragon appeared now, for the first time, on this new Coin, which, however, ceased to be struck shortly after its appearance. After the lapse of a few years, a complete change occurred in the Coins of this metal: the Noble and its parts were no longer struck; the Double Ryal received the appellation of *Pound Sovereign*, and was ordered to pass for 20*s.*; the Angel rose in value from 7*s.* 6*d.* to 8*s.*, and the *Quarter Angel* was first struck; lastly, to supply the places of the Half and Quarter Noble, *Crowns* and *Half-crowns* were struck in gold. Crowns were struck in this metal down to the reign of George III. Those of Henry VIII. bore the devices of a double rose and an escutcheon, each surmounted by the Imperial crown: hence their appellation. The Legend, HENRIC. VIII. RVTILANS ROSA SINE SPINA, accompanied the symbol of the rose; and in the area the initials of the names of the King and his Queens were at different times inserted.

English Coinage.

James I.—We pass over the intermediate reigns, as the changes which took place were confined to alterations in the value of the Coins, and a few trifling varieties in the devices; an attention to which, in this brief sketch, might lead to confusion without affording interest to our readers. The Coins of gold in the reign of this Prince were but of three kinds; the *Unite*, another name for the Pound Sovereign, constituted the chief Coin, and received its name from the union of the two crowns in the person of this Monarch; on the obverse is a bust of the King, on the reverse the royal shield of arms under a crown. The Crowns of gold retained their value of 5*s.*, but their devices were altered, and had reference to the Union; on one of the sides appears a rose and on the other a thistle, each surmounted by the Imperial crown; they were in consequence designated *Thistle Crowns*. The Angel is now of rare occurrence, but the want of it was less felt from the introduction of *Double Crowns*, valued at 10*s.*, and two of which constituted the Unite.

Charles I.—The Unite now took the name of *Guinea*, from the metal of which it was struck being procured by the African Company from the coast of Guinea; the value first assigned it was that of 20*s.*, from which it gradually increased to 30*s.*, but in the end fell to 21*s.*, at which it has since remained. The Double Crown now formed the *Half-Guinea*. *Two* and *Five Guinea pieces* also were issued, the former being equal in size to the Crown piece. All of these Coins bore, on the reverse, devices nearly similar to those impressed on the Crowns in silver.

George III.—Besides the Guinea and its Half, *Quarter-Guineas* were struck in the early part of this reign; but they were soon called in. The Two and Five Guinea pieces continued in circulation, and *Seven Shilling pieces* issued for the first time; but, from creating a confusion with the Half-Guinea, they gradually disappeared.

In the year 1815, all of the above were called in, and the *Sovereign* and *Half-Sovereign* substituted in their room.

The copper Coinage of England.

The Coins of least value which have circulated in England from the epoch of the Conquest, are the Halfpenny and Farthing; but these being struck in silver so late as the reigns of Mary and Elizabeth, will account for a Coinage of copper having been so long excluded from our Mint. Owing to the gradual decrease in the value of silver, the parts of the Penny had so much declined in size, that they were continually liable to be lost, and for this evil a remedy was sought by recourse to a metal of inferior value. Snelling divides copper Coinage into four parts, an arrangement which will answer our present purpose. Under the first division will be included the Tokens in lead, tin, and copper; the second, the copper Coinage instituted by Royal authority; the third, the town Farthings, and tokens of private tradesmen; and the fourth and last, all the pieces issued from the Mint, in copper, after the second institution by Royal authority of a Coinage of that metal. Class I. Tokens in lead, tin, and copper appeared in the reigns of Henry VIII. and Elizabeth, and are far from numerous. The Farthings of silver ceasing to be struck in the reign of the latter, it was found requisite that some Coins should be substituted for them. A memorial was in consequence drawn up, proposing an alloy of silver and copper; Elizabeth, however, expressed herself strongly averse both to a

Coinage of copper and to any debasement; the scheme in consequence fell to the ground. The pattern pieces struck on that occasion, on the obverse represent a bust of the Queen, and sometimes a rose surmounted by a crown; on the reverse is a monogram, occupying the field, in which the characters of her name are ingeniously interwoven. The Legend, THE PLEDGE—OF A HALFPENNY, is separated, one half appearing on each face. Class II. In the following reign the want of pieces of the above value was so generally felt, that tradesmen took upon themselves to strike tokens in copper and other metals; a process which, being justly regarded as an infringement on the Royal Prerogative, led at length to an authorized copper Coinage. This Coinage consisted solely of Farthings, chiefly struck during the reigns of James I. and Charles I.; the obverse represents two sceptres crossed, surmounted by a crown; the type of the reverse is a harp,—as it was designed to send them to Ireland had they been refused in this Country. Class III. The above Coinage was from some causes discontinued, and the distracted period of the Commonwealth succeeding, did not admit of attention to its revival. Hence private tradesmen resumed to themselves the privilege of striking their own pieces; and to such an extent did this system (almost peculiar to England) prevail, that no fewer than 3000 persons are reported to have issued their own Tokens. These pieces offer an infinite variety in their devices. Class IV. This last division commences in the reign of Charles II., when a Coinage of Halfpennies and Farthings of copper was issued by Royal proclamation. They bore, now for the first time, the device of Britannia, slightly differing from the figure on the current Coin. It was not until the reign of George III, that pieces of the value of a Penny and Twopence were coined.

We have now specified all the devices of importance to be found on British Coins, and when compared with those which have formed the subject of the preceding sections, their number will be found to be extremely limited. It has been frequently regretted, and we think not without reason, that a greater diversity has not prevailed among the symbols. Pope has observed:

> O when shall Britain, conscious of her claim,
> Stand emulous of Greek and Roman fame?
> In living Medals see her wars enroll'd,
> And vanquish'd realms supply recording gold?

ft's plan the im- vement British ns.

In the reign of Queen Anne, Dean Swift delivered to the Lord Treasurer a plan for the improvement of British Coins; in which he proposes, "that they should bear devices and inscriptions alluding to the most remarkable parts of her Majesty's reign." "By this means," he continues, "Medals that are at present only a dead treasure, or mere curiosities, would be of use in the ordinary commerce of life; and, at the same time, perpetuate the greatness of her Majesty's reign, reward the labours of her subjects, keep alive in the people a gratitude for public services, and excite the emulation of posterity. To these gracious purposes nothing can so greatly contribute as Medals of this kind, which are of undoubted authority, of necessary use and observation, not perishable by Time, nor confined to any certain place, properties not to be found in books, statues, pictures, buildings, and other monuments of illustrious actions." The scheme failed, like many others of a similar kind; all that was effected was the striking a small number of Coins, chiefly pattern pieces, the celebrated Farthings of Queen Anne. These Coins have been justly esteemed for their workmanship, but they are, with a few exceptions, by no means rare; and the greater number of them bearing only a figure of Britannia for the type of the reverse, are little deserving of notice.* Had the plan suggested by Swift been put in practice, it would at once have ennobled our Coinage, and have elevated it far above the rank of a mere medium of commerce.

Farthings of Queen Anne.

Armorial bearings.

The introduction of Heraldic ensigns, which we stated took place about the XIVth century, has prevailed in the Coinage of almost every European Power; and though symbols of that kind may be introduced with propriety, they have effectually led to the exclusion of all attempts at variety of design. The execution of the English Coins, at the present day, is equal if not superior to that of the Coins of every other nation.

Workmanship of English Coins.

The introduction of the Mill effected a material improvement in the appearance of our Coinage; and while under the direction of Thomas Simon it attained to great excellence. The Coins also of Queen Anne and of George I. are entitled to much praise. During the two succeeding reigns, the Arts generally were in decline, but they revived with George III. The thinness of our early Coins precluded the power of giving any considerable relief to the portraits, which constitutes one of the chief beauties of ancient Coins. And even now, in order to obviate the loss of metal occasioned by friction, the relief is kept extremely low. Greater attention, however, is bestowed on the detail; and, for neatness of fabric and delicacy of execution, the recent Coinage seems scarcely to be capable of improvement.

Coinage of Scotland.

The earliest Coins struck in Scotland have been referred to Alexander I. A. D. 1007, from which date down to David II. they continued of the same size and value as those of England, receiving thence all their improvements. The chief Towns appearing on the Coins of the above-named period are ED and EDENEBV, (Edinburgh,) PERT, (Perth,) ROCESBV, (Roxburgh,) BEREWIC. (Berwick.) Halfpennies and Farthings also were coined; with David II. the Groat and Half-groat, and in the XVIth century the remaining denominations of silver Coins. Gold circulated in Scotland about thirty years later than in England, and the Coins struck received the appellation of *St. Andrews Lions*, and *Unicorns*, from the devices which they bore. A Coinage of copper existed in Scotland at an earlier period than in England; a currency also was established of *Billon money*, or copper washed with silver.

Coinage of Ireland.

The Danes struck Coins in Ireland in the VIIIth and IXth centuries on the model of those of England; but so barbarous is their workmanship that the human countenance can scarcely be discerned, and in lieu of letters only strokes, IIIIII, appear. The Coins of the Irish Kings were struck in Dublin, but those of British Monarchs abound, also struck in that City, which resemble in many respects the Coins of England down to the reign of Henry VIII. Under that Prince, the badge of the harp was first assumed for Irish Coins. On the pieces struck from the reign of John to that of Henry V., the heads of Kings appear enclosed by triangles; and after the last-named Prince, they are distinguished by the names of the Irish Cities which they bear. In the time

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* One of Queen Anne's Farthings, dated 1714, was current. The two bearing Britannia under a Portal, and Peace with a Car are rare; that with *Bello et Pace*, 1713, is extremely rare.

of Elizabeth, Coins in copper as well as in the other metals were issued for Ireland; but upon the abolition of the Mint, in the year 1640, no more gold and silver was struck.

Sect. 3.—MEDALS, &c. &c.

The terms *Coin* and *Medal*, though materially differing in their signification, are frequently confounded; Pinkerton, notwithstanding he has made the distinction, has neglected to observe it throughout his Essay; but it is important they should be discriminated. *Coin* is applied to such productions of the Mint as were intended for currency as money; *Medal* to such as were struck in commemoration of events or in honour of individuals. The misapplication of the terms has probably arisen from the number of Numismatical Works which have appeared in the French tongue, and in which *Médaille* is employed in both senses.

The remarks offered upon the subject of modern European Coinage, are applicable in many instances to Medals also; such as an absence of character in the portraits, and a forgetfulness of the manners of the Time and Country in their devices. Among the peculiarities which distinguish the modern from the ancient Medals, may be mentioned the introduction of portraits of illustrious characters. It is remarkable, that while busts are found of many of the ancient Poets, Historians, and Philosophers of celebrity, their portraits never occur on Medals. On the other hand, no sooner had the Art of Die Engraving revived, than it became applied to the purpose of transmitting to posterity the portraits of distinguished individuals. Another distinction worthy of notice is, that modern Medals have frequently been employed as vehicles of Political satire; a practice which prevailed chiefly in the Low Countries. There is reason to believe that Satire, which has now quitted Medals for Prints, was not altogether unknown to the Roman Mint; it is certain, however, that it was but rarely practised.

Many of the early Medals, though defective in design, are pleasing from the boldness of the parts, simplicity of the forms, and force of relief; in the course of time we find greater attention bestowed on the detail and general appearance, their chief merit consisting in a display of the minuteness of Art. Among the symbols we frequently meet with the delineation of edifices of celebrity, of which perspective representations are given. The buildings represented on Roman Coins, on the other hand, are simple elevations. The personages of the Heathen Mythology are frequently introduced on Modern Medals, in connection with the events they commemorate; a glaring impropriety, which is rendered more apparent when we remember that these symbols, occurring on ancient Medals, strongly illustrate the manners of the Age.

The Legends on Modern Medals have been oddly divided by one writer into the Impious, Poetical, Jingling, Intricate, and Amusing, to which Pinkerton adds, Long Legends. We cannot find room to insert specimens of these strange varieties.

Modern Medals.

The first Medal struck in England is of Henry VIII.; it is in gold, and bears his portrait, and an inscription on the reverse. With Edward VI. the Coronation Medals commence, and from that reign Medals exist of all our Monarchs bearing symbols of a political nature. Those of the Commonwealth and Charles II. were executed by Simon, and have been engraved by Vertue. On the Medals of Queen Anne the splendid achievements of Marlborough are recorded, and shortly after Dassier, a Genevese, executed the Medals of the Kings of England and of many illustrious characters. Scotch Medals have been found of an earlier date than the English, one existing of David II.; it was struck in the XIVth century, is of gold, and formed upon the model of the Nobles of Edward III. The Medals of Mary are numerous, and the most interesting of the series.

The Papal Medals are the earliest, and at the same time most complete Modern series which exists; they commence with Paul II., 1464; there are, indeed, Medals to be found of Popes many centuries previously, but they were struck by the successors of the above. The common types on the reverses of these Medals are the cross keys and mitre; the obverse bears the head of the Pope, with or without the mitre. A few of the Popes, as Julius II. and Leo X., were so fortunate as to have the Historical devices on their Medals designed by the distinguished Painters of the Age, as Raffaelle, Julio Romano, and others. Medals abound of many of the Italian States, especially of Florence and Tuscany; a fine series is extant of the Medici family also. The most remarkable of the French Medals are those of Louis XIV., forming a complete History of his life. The German Medals appear with Frederick III., 1453, and are numerous of the separate States as well as of the Emperors. Medals begin in Holland, 1566, and are rendered chiefly conspicuous by the maps and plans delineated thereon, devices which, though they exhibit poverty in design, are nevertheless curious and useful. The Spanish Medals commence with Consalvo, about the year 1500. There are other series appertaining to Denmark, Sweden, and Hungary.

Distinction between genuine and counterfeit Coins.

It is highly important that a person desirous of collecting Coins, should be enabled to detect the forgeries of modern times, as we regret to say they prevail to a very great extent. This knowledge can be acquired only by a careful examination of Coins known to be false with such as are accounted genuine. The hints given in books, a few of which we shall subjoin, may be read with advantage preparatory to such an exercise, but of themselves they can contribute little to security. The means by which the Medallist is enabled to detect true from counterfeit Coins are so various, and depend upon such minute peculiarities, as not to admit of being suitably expressed in words.

No sooner had a taste for collecting Coins manifested itself than attempts were made to impose upon the ignorant; and the individuals engaged in these forgeries, so far from regarding the practice dishonourable, claimed to themselves especial merit for their skill in accurate imitation. Many of the European Countries have produced individuals who have acquired celebrity by this disgraceful practice: the most celebrated were two Italian brothers, the Cavini of Padua; their pieces are designated *Paduans*, and exhibit extraordinary skill. Carleran practised the same trade in Holland, Dervieu of Florence confined himself to Medallions, and Cogomier forged the Thirty Tyrants in brass. Pinkerton divides counterfeit Coins into six classes. They are as follows: I. Modern imitations of ancient Coins, which have acquired value from being fabricated by artists of eminence. II. Coins cast from the preceding. III. Coins cast from the antique. IV. Ancient Coins retouched, and the obverses and reverses altered. V. Coins impressed with new devices and soldered. VI. Counterfeit Coins which have clefts filed in them, and those which are plated.

The forgeries have been chiefly directed to perfecting the different series known to bear a high value; the Imperial Medallions and series in first brass, are consequently the classes in which they most abound. Forged Coins, from being cast, generally do not exhibit the same degree of sharpness as those which are genuine, the projections are more rounded, and those portions of the objects which unite with the ground are less strongly marked. The surface of the metal being corroded is no criterion of the genuineness of a Coin, as by an ingenious application of acids the effects of Time can be given with great nicety.

Directions for forming Cabinets.

Cabinets of Coins, as Pinkerton observes, may be considered as of three kinds: the first of these may be termed the Complete Cabinet, including the Coins of every Nation both ancient and modern; in the second the completion of one series is aimed at; and the third consists of an assemblage of specimens selected from the leading classes.

The complete Cabinet, from the great expense attending it, is rarely formed by individuals but reserved for scientific and learned Institutions. As the directions for the formation of this Cabinet will apply, however, in part, to the remaining two, and as it should form their basis, we shall lay down the method we conceive the most desirable.

In the classification of Coins, an alphabetical arrangement was formerly rendered subservient to every other, with a complete disregard of time and place. A system more accordant with truth, is that in which the alphabetical order is made secondary and introduced only to facilitate reference.

The Coins of the Greek Cities and Free States take the lead, observing the following order with the Countries:

EUROPE.

Spain.
Gaul.
Britain.
Italy.
Sicily.
Sicilian Isles.
Mœsia.
Thrace.
Macedon.
Thessaly.
Illyria.
Epirus.
Corcyra.
The States of Northern Greece.
Eubœa, Crete.
Egina, Cephallenia.
Zacynthus, Ithaca.
The Peloponnesus.
Isles of the Egean Sea.

ASIA.

The Countries of Asia Minor.
Ionian and Carian Isles.
Armenia.
Commagene.
Syria.
Seleucis.
Cœle Syria.
Phœnicia.
Judæa.
Edessa.
Parthia.
Persia.

AFRICA.

Ægyptus.
Cyrenaica.
Zeugitania.
Numidia.
and
Mauritania.

The Coins of the Cities in each Country may be disposed alphabetically, the gold taking precedence of the silver, and the silver of the copper. The Coins of the Greek Princes class with the respective Countries.

The Roman Coins will succeed in the following order:

Roman *Asses*, arranged in sets.
Coins of the Roman Families in alphabetical order.
Imperial gold coins; Imperial silver Coins.

Arrangement of Coins in a Cabinet.

Imperial first brass; second brass; third brass.
Imperial *Minimi*, including the *Quinarii* of gold and silver, and the smallest of the copper Coins.
Imperial Medallions of all metals.
Imperial Greek Coins; Colonial Coins.
Coins of the Emperors struck at Alexandria, generally in base metal.
Lastly, Coins of a few Gothic Princes, of the early Eastern Nations, &c.

In the Modern department, the Countries are arranged chronologically, with the exception, however, of England, the Coins of which, from the great perfection of the series and the interest thereunto attached, may, at least in an English Cabinet, take precedence of the rest. When the Coins of any one Kingdom are very numerous, they may be classed according to their dimensions, in which case it will be found, that the Modern silver Coins fall under three sizes: thus we have the Penny, which for many Ages constituted the sole Coin; the Groat, a Coin of some importance for a considerable period and existing to this day; and, lastly, the Crown-piece from the commencement of the XVIth century.

The Cabinets formed in England are chiefly of the second kind, in which the collector has had in view the perfecting of a single class, whether Greek, Roman, or English Coins, the last in all probability very naturally being the most extensive. When the series of Imperial Coins in first brass cannot be perfected, from the excessive rarity of those of a few Emperors, the second brass may be substituted; also the small brass resorted to in order to complete a series in the middle size. The same may be done in the Roman gold and silver Coins, otherwise it would frequently be impossible to form a sequence. When the Imperial Coins are not numerous in a Cabinet, they may be classed with the Roman Imperial, and follow in the order of the Emperors.

The third Cabinet or Casket of Coins, as it may be termed, will, from its variety, prove more generally interesting than the two preceding; an attentive examination into the above arrangement will suggest the best method of disposing of the Coins, but much must of necessity be left to the judgment and fancy of the collector.

Numismatical Writers.

A full and accurate description of Grecian and Roman Coins will be found in the *Doctrina nummorum veterum* of Eckhel; the Work is extended to eight quarto volumes, and is without question the most complete of its kind. The writings of Patin, Jobert, and Pinkerton take the lead among the elementary productions; the *Essay* of the last, though occasionally deficient in accuracy and perspicuity, forms on the whole the best introduction to a knowledge of the study that has yet appeared. The Grecian Coins are detailed in the Works of Goltzius, Magnan, Gessner, Frœlich, and Pellerin, some of which are little more than extended Catalogues of Coins. Vaillant has written at considerable length on the Monarchic Coins, as well as the authors just mentioned; a very good general knowledge of this class of Coins may also be obtained by a perusal of *L'Iconographie Grecque*, by E. Q. Visconti. A small Work entitled *Numismatique du Voyage du Jeune Anacharsis*, by Dumersan, gives a concise account of the most important of the Grecian Civic Coins, and is beautifully illustrated.

In the division of Roman Coins, Vaillant and Morel have each left excellent Works on the Coins of the

Families; for those of the Empire that of Vaillant is the chief, and it is brought down to the extinction of the Western Empire; for the remaining Coins, Banduri may be consulted. Addison's *Dialogues on the Usefulness of Ancient Medals* treats only on the Coins of the Emperors in first brass, and contains many excellent remark upon the utility of the study at large.

A complete History of the Coinage of England is afforded by Ruding's *Annals of the Coinage of Britain;* it is accompanied by a Volume of Plates executed with great care, and containing representations of all the pieces that have issued from our Mint. Snelling's *Tables* have long been popular: they form a good catalogue of English Coins, and are valuable to the collector as a Work of reference, but the preceding Work offers every information on the subject that can be desired. For Scotch and Irish Coins, Anderson and Simon take the lead; for the French, Bouterone and Le Clerc; for the Papal Coins, Floravantes; Argelati for those of the Italian States, and Florez for the Spanish.

The value and proportion of the Ancient Coins have formed the subject of a Treatise by Arbuthnot, and the Tables which it contains, notwithstanding their great inaccuracy, have been frequently transcribed: we have endeavoured to rectify these errors in the Tables above given for the Greek and Roman Coins, but a complete Work of the kind is much wanted.

A Table, exhibiting the Comparative Value of the chief Gold Coins of Modern Countries reduced to the standard of England.

	Countries.	Names of Coins.	Current Value.	Value in Sterling. £.	s.	d.
	England.......	**Sovereign*	20 Shillings	1	0	0
	France	*Piece of 20 Francs (*Napoleon*)	. . .	0	15	10
	Netherlands....	10 *Guilder*, or *Florin Piece*	. . .	0	16	5¾
	Holland	**Ryder*	14 Florins or Guild^s.	1	4	9¼
	Denmark	*Pistole* (Christian d'or)..	. . .	0	16	6
	Russia	**Half-Imperial*	5 Rubles	0	16	1¾
	Austria........	**Sovereign*	. . .	0	13	11
Germany.	Bavaria ...	*Max d'or*	7 Florins 8 Creutzers	0	13	7¼
		Carolin	10 Florins 42 Creutz.	1	0	4¼
	Wirtemburg	**Pistole*	. . .	0	16	4½
	Brunswick .	**Pistole*	. . .	0	16	4½
	Westphalia	**Pistole*	10 Thalers	0	16	3¾
	Saxony ...	*Do. (Auguste d'or) ..	. . .			
	Hanover ...	Do. (George d'or).....	. . .	0	16	4½
	Prussia	**Pistole* (Frederick)	. . .	0	16	3¼
Italy.	Milan	**Pistole*, or *Doppia*	20 Lires	0	15	7¾
	Piedmont .	*Pistole*, Do.	20 Lires	0	15	10
	Parma	**Double Pistole*	40 Lires	1	14	1¾
	Tuscany ...	*Ruspone* of Etruria	40 Lires	1	8	6
	Rome	*Scudo* of the Republic ..	. . .	3	4	11¾
	Sicily	**Ounce*	60 Tari	0	10	3½
	Switzerland	*Pistole* of the Helvetic Republic	24 Livres	0	18	8¾
	Spain	**Double Pistole*, or *Doubloon*	. . .	1	11	10¾
	Portugal.......	**Half Joannese*	6400 Rees	1	15	8¼
	Turkey	*Sequin*	The number of Piastres vary	0	7	7
		Messeir		0	2	1¾
		Yermeebeshlik	. . .	0	12	5¼
	United States ..	**Eagle*	10 Dollars	2	3	6½
	India	*Mohur* (Bombay)	15 Rupees	1	8	10½
		*Do. (Company's)..		1	9	2¼
		*Do. (Madras)		1	12	10¼
		Star Pagoda	4 Rupees	0	7	4¾

* These have their Doubles, Halves, &c. in proportion.

Note. The *Ducat*, varying by the above computation from 9*s.* 2*d.* to 9*s.* 4¾*d.*, circulates throughout Germany, Switzerland, and most of the Northern European Countries, as Denmark, Sweden, and Russia: it has also its Double and Half. This Coin is also common among the Italian States, where it passes under the name of *Sequin;* in Venice it is termed *Chequin*, or *Zecchino*.

A Table, exhibiting the Comparative Value of the chief Silver *Coins of Modern Countries, computed at the rate of* 5s. 2d. *per ounce, standard.*

Countries.	Names of Coins.	Current Value.	Value in Sterling. s.	d.
England	*Crown* (½ in proportion)	5 Shillings	4	8¼
France	*Franc* (½ in prop., also 2 and 5 Franc pieces)	100 Centimes	0	9¼
Holland	*Florin* (30, 12, 8, &c. Stiver pieces in prop.) .... 63 Stivers constitute the *Ducatoon*, 50 the *Rix-dollar*.	100 Cents, or 20 Stivers	1	8¼
Denmark	*Krone*, or Crown, ⅔ of *Ryksdaler* .	4 Marks	2	10½
Sweden	*Rix-dollar* (½ in prop.)	. . .	4	4½
Russia	*Ruble* (½ and ¼ in prop.)	100 Copecs	3	2¾
Prussia	*Gulden* (Florin) ½ in prop.......	24 Groschen	2	3¼
Germany	*Thaler* or Dollar (½ and ¼ in prop.) The Thaler is the measure of value throughout the German States.	. . .	3	11
Hungary	Krone	. . .	4	3¼
Switzerland (Geneva)	*Patagon*, or Crown (½ in prop.) .. This Coin varies in each of the Cantons.	3 Livres	3	11
Italy .... (Rome)	*Scudo*, or Crown (½ in prop.) .... The Scudo is the chief silver Coin of this Country, but is subject to great variation in the several States.	10 Paoli, or 5 Lires	4	2½
Sicily	*Scudo* (½ in prop.)	30 Taris	4	0½
Spain	*Piastre*, or Dollar	10 Rials	4	3¾
Portugal	*Crusado* (½, ¼, &c.)	480 Rees	2	3½
Turkey	*Piastre* (½ and ¼)	40 Paras	0	9½
United States.	*Dollar* (½ in prop.)	100 Cents	4	3¼
India	*Rupee*	16 Anas	1	11

Note. For the Spanish, Portuguese, and Dutch settlements on the Continent and in the West Indies, see the Coins of the respective Nations.

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The difficulty of giving a clear and succinct definition of the Art of Poetry is proportioned to the almost universal nature of its subjects. In common with the studies of Theology, Ethics, Oratory, History, and of Legislation, so far as it is connected with the broad Principles of Ethics, it is obviously distinguished from those Sciences conversant either with the Physical wants, or the speculative curiosity of Mankind, its proper field being our Moral, Social, and Reflective nature. Again, it differs from the rest of the Sciences thus conversant with a common material, as professing neither the office of persuasion nor of instruction. Its province, in the employment of the common medium of Language, is imitative and expressive, and its end is Pleasure; of a refined and intellectual nature it is true, and capable of promoting the highest Moral ends, but still exclusively Pleasure, as in the kindred Arts of Music and Painting. It is certain that Historical Truth, Moral instruction, or Oratorical persuasion, may be embodied in Poetry; but thus also do History, Ethics, and Rhetoric in their turn appeal to the Imagination by those graces and ornaments which belong more peculiarly to Poetry. It is the respective end sought by each Science, which must determine both its nature and the rules defining its peculiar excellences.

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That Pleasure is the exclusive end of Poetry, does not necessarily compromise either its dignity or usefulness. As Mental Pleasure is the indication and the test of the formation of those Moral habits on which it is attendant, an Art productive of this result from the representation of Moral sentiments, and the actions arising from them, must be guided by those rules which determine their merit. It will be in fact found, that with very few exceptions, Poetry has adapted itself to the highest tone of Morality prevalent in the Country or Age wherein it has flourished. Mankind are obviously more Moral in theory than in practice, reprobating the imaginary picture of vices even to which themselves are prone, and delighting in the highest imaginary model of such virtues as themselves possess in a minor degree; and the fallacy of the vicious man arises not so much from a denial of the Principles of Right and Wrong, as from a refusal to adapt them to his own case. Thus the difference between a man's real Moral merit, and his own conception of it, will generally measure the superiority of the tone of popular Poetry over the existing standard of average Morality, regard being had to the spirit and Religious creed of the Age. The Greek and Roman Poets accordingly dwell strongly on Justice, Patriotism, Reverence to the Gods, to old age, to the Laws of our Country, in short on all those duties which cement the Social compact. The Scalds, on the contrary, so far as we can judge from the relics of their rude rhymes, strove to give the most exalted tone to what were considered as the highest virtues among a Nation of Pirates, whose very Gods were fabled as living in a perpetual state of battle and mutual destruction, to be brought to a more perfect crisis by the coming of Lok. Their precepts are inhuman, simply because public opinion then recognised Moral excellence as consisting in qualities the very reverse of humanity. Here we see Poetry adapting itself respectively to the highest, and to the most dangerously brutalized degree of the light of Nature, but in both instances inculcating the loftiest Principles of Ethics which its hearers had derived from that light. In spite therefore of the denunciations of Plato against Poets, as corrupters of his imaginary Republic, it may be safely affirmed that their province is rather to second the efforts of the Moralist and Legislator, and that when the tone of National Poetry is corrupt, it is only a proof that the existing standard of Morality is so also in a double degree.

Poetry.

> Her track, where'er the Goddess roves,
> Glory pursue, and generous Shame,
> Th' unconquerable Mind, and Freedom's holy flame.*

How far amenable to the laws of Truth.

Nor again can it be properly said that Truth is one of the objects of Poetry, further than as that probability, which the Poet is bound not to violate, is founded on a general induction from facts as they really take place in the Moral or Visible World. The subject of his Art is not that which *is* in any particular instance, but that which generally may be. In no case does he attempt to assert or prove any specific matter of fact; and even in Didactic and Reflective Poetry, which may be considered as a mixed branch, he seldom aims at more than to shadow out pleasurably certain general Principles. The most perfect Tragedy or Epic Poem may not necessarily contain a word of Truth in it, any more than the dreams which madmen often form with the most ingenious coherency on an assumed hypothesis; and in both cases there is a sound basis consisting in the experience which the Mind has acquired as to the connection of causes and circumstances. Thus, assume that Ulysses was a person really existing, of the rank and character described by Homer, and meeting with the persons and adventures exhibited in the *Odyssey*, and every thing which he does and says is admirably consistent with the inductive view of Human Nature which the reader's previous experience enables him to take. Again, the wildest dreams of Poetry cannot come home to the fancy with much pleasure, unless they are founded on something analogous to Truth and Experience, or to some home-bred prejudice or recollection which has impressed itself previously on the Mind with the force of reality. The Fairies in the *Midsummer Night's Dream* act and speak in a manner exactly conformable to the notions which superstition has gravely promulgated of such half-human elves, and which the playful legends of the ingle-nook and the greenwood tree made "familiar as household words" to the imaginations of our ancestors. Nay even in the marvellously original creation of the monster Caliban, it is the Metaphysical Truth which renders palatable a fiction which our sober judgments directly pronounce impossible. Once suppose a Being compounded of Demon and Savage, and according to the distinct ideas existing in our Minds respecting these, their actions and language would mingle just in the proportion exhibited in the character of "the poisonous slave, got by the Devil himself." Suppose also a spark of Divine benevolence infused into a Spirit moulded from the essence of wild flowers and zephyrs, tempering and humanizing the Fairy sportiveness which we should associate with such

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* Gray, *Progress of Poesy*.

a compound, and we have a Being answering to the Familiar Spirit Ariel, whose lineaments and passions the Poet has, with great judgment, indicated in a less distinct manner than those of his grosser counterpart. Thus is Poetry amenable to Truth as an ultimate, though not an immediate test; and therefore cannot be said to profess or absolutely to violate it.

Not only imitative but expressive.

The definition of Poetry recognised by the Ancients, as an Art imitative of Human manners, is obviously too extensive to meet our modern ideas, inasmuch as it equally applies to Prose fiction, an important branch of Literature almost peculiar to modern times. Nor again does it seem sufficiently extensive to include those many varieties of metrical composition, equally common to ancient and present times, which cannot be called imitative in any other sense than Oratory or spontaneous Language can be so denominated; where, for instance, some Moral Truth is inculcated by the Poet, or some feeling congenial to the Mind of his readers is expressed by him in his own person. These are the sole elements of composition in Goldsmith's Poem of *The Traveller*, full as it is of dignity, high feeling, and a Poetical spirit which never flags. And to instance a still higher style of composition, Milton's *Hymn to the Deity*, though introduced as a part of his imitative fiction, is a composition complete in itself, as the exalted expression of a Religious feeling adapted to all times and situations, and is rather expressive of the sensations which the grand phenomena of Nature are adapted to create in a well-constituted Mind, than imitative of the objects which it invokes. It is equally perfect without the assumption of any person or circumstance, though placed with great dignity and propriety in the mouth of Adam during his state of innocence.

The same distinction may be laid down as to Elegy and Satire, and also as to Lyrical Poetry when not mingled with the legends and narrative descriptions in which Pindar delights; in short, as to all branches of composition in which the Poet addresses the reader in his own proper character, and without the intervention of any fictitious personages or things. Here the office of Poetry may be styled chiefly expressive, and no further imitative than as it employs sounds and metre adapted to strengthen the image of the thing described. It is most completely imitative in that branch which seems to have dwelt more peculiarly on the mind of Aristotle in forming his definition, *viz.*—the Drama; where the imitation is strengthened by the additional aid of vocal utterance, personification, painting, and expressive music.

As distinguished from Imaginative Prose.

The distinction of Poetical fiction from Imaginative Prose is obvious enough, although the bounds which divide their departments are but small, and consist chiefly in circumstances belonging rather to manner than to matter, connected with Poetry rather as inseparable accidents than as essential parts. We mean that metrical form which is the only visible sign distinguishing indifferent Poetry from Prose, while it is a necessary feature in that of a superior sort; as well as those ornaments of figure and diction which increase the force of metrical composition, but in Prose would seem bombastic and extravagant.

> *Fulgores nunc terrificos, sonitumque, metumque*
> *Miscebant operi, flammisque sequacibus iras.*

Of these we shall treat in their place, as connected with the external parts of Poetry, belonging as they do to the Art in every branch, and distinguishing it from Romantic Prose; which in respect to its matter and its end, has every feature in common with Poetry as an inventive and imitative Art, and admits mostly of the same rules as a test of its excellence.

Definition of Poetry.

It should appear then that we may define Poetry as an Art aiming at Moral and Intellectual Pleasure as its sole object, and promoting that Pleasure through the medium of metrical language, by the imitation of such things or events as affect the feelings and imagination, or by the expression of the sensations which they produce.

Origin of its Metrical form.

Its origin, as inseparably connected with Metre, appears to us to have arisen from causes intimately allied with Human Nature even in the rudest stages of Society. It is in public that mankind instinctively seek to give vent to those emotions which arise from common subjects of interest; such as the worship of the Deity, the commemoration of public benefactors, or of political events; a victory, or a reverse. In small and rude States contending for very existence, such causes of emotion would be most intensely felt. Every individual in an assembled crowd would seek to join in the expression of gratitude or deprecation to his Divinity, of honour to his chieftain, or of defiance to the common enemy; and *that* in a manner expressive of his sympathy with those around him. The most discordant shout bears thus as distinct a meaning as a war-cry, or the solemn assent to the supplication of the Priest, of which we have preserved a remnant in our Christian worship. These were probably the earliest modes in which the voice, the natural organ of emotion, sought to express itself in a great assembly; accompanied, perhaps, on some occasions by such rough and primitive instruments of Music as were known to earlier times. Nothing possesses in itself so imposing an effect on the imagination as a mighty and overpowering sound, such as that of thunder or a stormy sea; and when expressive of the unanimous feeling of the Many, the Moral grandeur superadded thereby renders it doubly animating. The observance of this effect, and the improvement of the rude drum or horn into instruments harmonizing with the natural modulations of the human voice, would naturally lead inventive spirits to devise some means by which human and artificial sound could be so blended as to express more copiously and connectedly the common feelings of large assemblies. It is obvious that this end could not be effected without something in the shape of Metrical arrangement, analogous to those means by which multitudes must learn to execute any common bodily movement in concert, and without confusion, and adapted to assist the retentive powers of the Memory and the ear. Thus, probably, rude war-cries and shouts of victory were gradually blended into Triumphal choruses, and the Religious responses of the populace became connected Hymns; the Bard or Priest acting as the Coryphæus, and regulating the voices of the singers as the file-leaders would arrange the march of an army. In progress of time, the success and popularity of these first rude invocations to Gods and Heroes would naturally lead their composers to enlarge gradually the sphere of their efforts, according to their different bents of Mind. The legends relative to Heroes of elder date, and the fabled adventures and transmigrations of their Gods, would afford a wide field for the first attempts at Narrative Poetry, to some of this privileged class; others of a more meditative turn would, like Orpheus, embody precepts of Ethics and Legislation in a form adapted to impress itself on the Memory, and, as it were, consecrated by its connection with Divine subjects; while those of a more enthusiastic and mystical frame of Mind would proclaim through the same medium the results of their auguries and fancied inspirations, to a people prepared to listen and flatter them in their belief of Divine revelation. Hence was it in all likelihood, that the names of Poet and Prophet became synonymous in the Classic Languages, by a sort of ancient prescription. Nay, it should seem that, even in the worship of the true God, the same correspondence in name and vocation prevailed, if, as has been conjectured with apparent truth, the Schools of the Hebrew Prophets were Institutions for the instruction of youths in the studies of Eloquence and Sacred Poetry, as chosen vessels upon some one of whom the Divine gift of Prophecy might descend for some special purpose.

radual tension of subjects.

The Art of Song being thus familiarized among Mankind as the expression of the greater and more sublime emotions of the Mind, would in process of time be gradually applied to other subjects of engrossing interest. The love of our Country, of fame, of woman, of kindred, of sylvan nature, or of manly sports; all passionate retrospects to the past, or anticipations of the future; these form the continual day-dreams of ardent Minds when not engaged in positive action. It is partly from the desire to mark the eras of Life and Thought formed by such feelings as these, and partly from the shrinking sensation with which the extinction of that Life and Thought is contemplated, that almost in every stage of Society, Mankind have sought to embody in as lasting a shape as possible, the records of their ruling emotions. The same yearning after human sympathy and posthumous identity which prompts the shipwrecked seaman, or the captive, to trace their names on their dungeon-wall or solitary rock, or the traveller to inscribe a record of his adventures in the mountain *hospice;* which even, unconsciously to himself, impelled the misanthrope Timon to utter his last defiance to Mankind in his Epitaph;—inspires the Poet with the desire to perpetuate his own feelings and recollections, and to rescue from oblivion the name of his friend, his mistress, or his benefactor; blending as it does with the hope and stimulus of posthumous fame.

> The Bridegroom may forget the Bride
>   Was made his wedded wife yestreen;
> The Monarch may forget the crown
>   That on his head an hour hath been;
> The mother may forget the child
>   That smiles sae sweetly on her knee;
> But I'll remember thee, Glencairn,
>   And a' that thou hast done for me!
>
> *Burns.*

Some of the noblest instances of this tone of feeling are to be found in the Odes of Pindar, where the somewhat vain-glorious tone of the Poet is redeemed and borne out by the passionate desire of immortality which breathes in every word, and his manly confidence in the dignity of an Art destined to confer that immortality on the actions of the Wise, the Valiant, and the Just.

> Φιάλαν ὡς εἴ τις ἀ-
> φνειᾶς ἀπὸ χειρὸς ἑλὼν,
> Ἀμπέλου ἔνδον καχλάζοι-
> σαν δρόσῳ, δωρήσεται
> Νεανίᾳ γαμβρῷ, προπίνων
> Οἴκοθεν οἴκαδε, πάγ-
> χρυσον, κορυφὰν κτεάνων,
> * * * *
> * * * *
> Καὶ ἐγὼ—κ. τ. λ.
>
> *Olymp.* carm. 7.

> Οὐκ ἀνδριαντοποιός εἰ-
> μ', ὥστ' ἐλινύσσοντά μ' ἐργάζε-
> σθαι ἀγάλματ' ἐπ' αὐτᾶς βαθμίδος
> Ἑσταότ'. Ἀλλ' ἐπὶ πάσας
> Ὁλκάδος ἔν τ' ἀκάτῳ, γλυκεῖ' ἀοιδὰ
> Στεῖχ' ἀπ' Αἰγίνας, διαγγέλ-
> λοισ'—κ. τ. λ.
>
> *Nemea*, v.

Fostered by the Polytheism of the Ancients.

In the system of Heathen Polytheism, also, there was hardly a spot which had not its Local Genius, and scarcely a Principle of Human Nature which was not embodied in the imaginary shape of some one God or Goddess. Hence the pride felt in an Art difficult of acquirement in its first technical steps, was additionally flattered by the supposition of a Divine influence felt through every branch of it; and the ardour of composition (a feeling so peculiar that it was honoured with a distinct name, *Awen,* among the Welsh Bards) was readily imagined by the Heathens to arise from this influence. Thus the invocation of the Muse, which nothing short of the genius of Milton can in modern times make otherwise than a trite and solemn farce, bears in the mouth of Homer the semblance of fervour and truth.

Origin of Satire.

The early prevalence of Satiric Poetry, which should seem at first more congenial to periods of higher refinement, may be traced according to the records left us, to the natural rivalry between the professors of an admired and highly privileged Art, a rivalry which in modern times is kept within bounds by public opinion and good breeding; but which in a rude state of Society would break into open feud. Among the Welsh Bards, who in addition to their national temperament, often combined the character of Warrior with that of Poet and Historian, it is recorded in some instances to have ended in single combat and death. The early Wits of Greece, such as Archilochus, Hipponax, and others of the Iambic School, not being bound by the Gothic law of honour, seem to have resorted to the more safe and characteristic weapon of the pen, and in one case, it is said, with equally fatal effect.* Nor were they probably backward in turning to more general account a method of annoyance, whose efficacy they had proved on the persons of their rivals.

Improvement of the Drama.

Our preceding observations on the Origin of Poetry in general, will, if correct, apply to the Epic, the Didactic, the Elegiac, and indeed to all the leading branches of the Art. Among the Greeks, to whom it is needless to say that we are indebted for the most perfect early specimens of all its essential departments, the Public Games and National institutions contributed to draw forth Poetic genius in every branch, more peculiarly in the Epic, Heroic, and Lyrical. It should seem that the public taste had been to a great degree developed in these respects, before the Drama received much improvement from its rude and primitive state. If the early records which we possess on this subject are interpreted by simple common sense, they strip it of the fictitious importance which some are disposed to annex to it. From the name and history of both its branches, we know that the prize given to the successful candidate in the one was the most carrion of domestic animals, and that the other probably consisted of a string of such local jests as might be more favourably received at the joyous seasons of the vintage and the harvest-home. Thespis himself and his contemporaries, declaiming from a cart, and

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* The suicide of Lycombes was imputed to mortification caused by the Iambics of Archilochus, when disappointed of the hand of his daughter.

painted with lees of wine, appear very much on a footing with the itinerant buffoons who still exhibit their red and party-coloured visages on similar occasions; and even the second character, introduced by them to complete their interludes, was probably of no higher caste than the Clown or Merryman, who is to serve as the butt of his principal's wit, and hardly on a footing with Arlequin, Jocrisse, Sganarelle, and the joculators by prescription on the stage of the modern Continent. The lively postures and gesticulations, however, which are natural to Southern people, and the obvions advantages of Dialogue and personification even in their rudest form, must soon have naturally suggested to Æschylus and the real founders of Tragedy, the possibility of applying successfully such aids to graver subjects. Thus is it the privilege of Genius to avail itself of materials at first sight discordant with its object.

It is not, however, so much our purpose to define or minutely to descant on the different styles of Poetry, as to state to the best of our power the general Principles applicable to the Art in all its branches, by an adherence to which its end as a source of intellectual pleasure will be obtained.

Components of Poetical Genius.

That Fancy and Judgment are respectively the moving and the regulating powers of the Poet's Mind, it is unnecessary to demonstrate. The former strikes out the material, or draws it by a sort of Chemical attraction from every source within its ken; the latter directs its use. Most persons, even the most illiterate, can generally describe with accuracy and strong feeling any thing which has interested themselves individually, so as to convey a very lively impression of it to the Minds of others. Here, however, the powers of the World in general stop short. A man is not a portrait-painter because he can convey in person a more faithful impression of his own features than can be given by the pencil of a Lawrence or a Reynolds. To transmit to the Minds of others a clear conception of circumstances, and characters foreign alike to the personal experience of the author and reader, to invest the meagre outlines of History, and the abstract creations of Fable, with colouring, speech, and motion,—to place familiar ideas in a new, striking, and dignified point of view,—to give a faithful image of some uncommon combination of passions and motives,—to draw the veil from before those manifestations of the real man, which the restraints of Society seldom allow to be witnessed,—this is the privilege of real genius alone; a power only to be matched by that of the fabled Dervise, who could infuse his spirit into dead matter, and personate the bearing, actions, and thoughts of its original tenant. It may be safely asserted that this power, when it once exists, implies a facility in all the less difficult attainments of the Art. Judgment and Experience are necessary to control its exercise, and Study to enlarge its field, but they cannot impart the faculty itself. It should seem to consist in a certain Metaphysical instinct, analogous to the wonderful powers of animals in accomplishing their own limited objects; bearing the same reference to the effects of Study, as the instinct of the Bee does to the Science of the Architect, and probably accompanied by great sensitiveness of organs and feelings, enabling the Poet to conceive and retain simple impressions in the clearest and liveliest manner. This natural gift, if accompanied by a meditative turn of Mind, a keen relish of the beauties of simple Nature, an acuteness in distinguishing essential properties from accidental in the Moral and Material World, and an impartial spirit of candour and good faith in entering into the different motives of Mankind by turns, is, as far as we can judge, that which constitutes a really great Poet, as distinct from the aids which may be acquired by Study and Experience. Homer and Shakspeare appear to have been the persons most distinguished for this gift of mother-wit; the latter, indeed, in a high and remarkable degree. How he soared from the Visible World to more subtle and immaterial conceptions, is intelligibly shadowed out in the passage from his Works which has been too often quoted and repeated to need any repetition; and in spite of the day-dreams of the more mystical and fanciful Critics, who would refine away common sense, we conceive that there is nothing implied in such a process beyond those acute powers of conception and intellect which we have attempted to analyze. It is true that there are many points relative to the nature of Mind, and to its connection with Matter, which if fully explained, might throw a light on the subject of Poetical genius and invention. Such are the association of ideas, the state of the Mind during dreams, the recurrence, at long intervals of time, of particular trains of thought, bringing back the visible form and colouring of spots forgotten, and passing vividly for an instant like a momentary gleam of sunshine on a distant object in a landscape; these, however, are rather to be explained by Psychologists, to whom they have long served as stumbling blocks. It is perhaps sufficient for our own purpose to assert that there is no subject of Poetry which has not its basis either in the passions of Mankind, or in the impressions conveyed to their different organs by the visible and tangible creation around them. These materials, it is true, will be more various and abundant in proportion to the acuteness of different Minds and temperaments, and for the same reason will be handled with different degrees of power and selection; but in any case they must remain in substance the same.

Much also of what is called Poetic Inspiration may be traced to the natural causes of familiarity and use; the acquired pleasure superadded by these to that arising from a natural bias in favour of the subject adopted, and the facility which they confer in the exercise of this and all other Arts. And without entering into any fanciful question as to the supposed analogies between words and things, it is obvious that a greater clearness of thought is both acquired and communicated by practice in Poetical diction, and study of the indefinable shades between one synonyme and another, answering to the different ways in which the same thing may affect the feelings and associations. On this part of the subject, it is our purpose to remark, when we treat of Diction, the importance of which in Poetry is perhaps rendered more forcible, by the consideration that even in real life and business, the impressions of things depend on the most minute differences between words. The most fatal misunderstandings and contests have arisen in real fact, from the iujudicious use of synoymes in the discussion of points of political jealousy or private honour. Much more necessary, therefore, is their study, when the impression of the moment is the only result sought.

A strong and vivid Memory is of necessity implied in the Poetical temperament above described. Perhaps, however, its importance is felt in nothing more than in retaining a lively impression of those feelings of childhood, which when brought back to the Mind of the grown man, present, as it were, a Fairy vista of pure Poetry. In childhood, when passed under circumstances favourable to the Mind and the Body, the former creates its own Paradise in a manner which has occasioned the beautiful, though somewhat fanciful, speculation of Wordsworth, summed up with

> Heaven lies around us in our infancy.

Without adopting the entire theory of this amiable and original author, it may fairly be asserted, that our own early recollections, and the formation of ideas in the Minds of children are not more beneath the study of a real Poet, than the process of blowing air bubbles was inconclusive in establishing a point in the discoveries of a Newton. If we could convey to our own imaginations the exact impressions formed in the mind of a lively child, basking in apparent idleness on a green bank in June, amid the hum of bees and the song of birds, they might be found to contain much of the real substance of what we admire when expressed by Spenser or Theocritus. The perceptions of all outward objects, and the feelings immediately resulting from them, possess at that age a clearness, a strength, and a simplicity, akin to that mood in which we most readily resign ourselves to Poetical illusions; and the perfect leisure from more serious thoughts and projects then enjoyed, leads to a hundred vague and undefinable musings, which, if they could be caught and treasured up for future years, would form an inexhaustible fund from which to refresh the imagination, but which are generally effaced by the discipline of active or argumentative life.

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Next, as to the subjects properly adapted for the exercise of the Poetical talent. These, if we may be allowed somewhat to extend the definition of Aristotle, are exclusively Human fortunes, actions, and passions, of a sort familiar to the reader: as well as those imaginary circumstances bearing a recognised resemblance to them, and those Moral and Physical causes which influence them immediately. For from sources directly or indirectly connected with our own mental habits must be derived, in every case, the Pleasure which it is the office of Poetry to afford. When this Pleasure is not felt, the fault must arise either from the nature of the subject, or from the defective mode of treating it. It is probable that were the highest powers of Poetry exhausted on such subjects as the Monkish dogma of the Immaculate conception, or the demonstration of Euclid's XLVIIth Problem, they would fail in producing any effect; for although both subjects have respectively influenced Human life for Evil and Good, they possess nothing in themselves to affect the Moral and Sensitive parts of our natures. Again, the subject of the Universe, as appealing to our highest conceptions of the Sublime and Beautiful, and our loftiest feelings of veneration and gratitude, presents a task to be grasped, like the bow of Ulysses, only by a master hand of the first order, and that with a nicety of judgment which genius does not always possess. Milton, accordingly, in the *Hymn* already quoted, which perhaps may be said to exceed all Human Poetry in true grandeur, has embodied all these feelings and conceptions in comparatively a few lines, taking his station like the Archangel between Heaven and Earth, above all associations exclusively Human. If, on the contrary, we may guess from obscure tradition, it should seem that the long Poem of Empedocles on the same subject led by its ill success to his suicide, probably because his superior Physical knowledge led him to load and mystify his theme with details fitter for a Scientific Work in Prose.

Again, in the treatment of those subjects recognised by our definition as fitted for Poetry, regard must be had to the influence of climate, habits, hereditary associations, and all those circumstances which contribute to form as it were the mental idiosyncrasy of the reader.

Influence of National temperament.

The skilful versification of Sir William Jones and other Oriental translators has been exerted in vain to awaken any interest in the ingenious conceits and voluptuous images which form the essence of Persian Poetry, and which, if we may judge from their effects on a cultivated and imaginative People, were probably treated in a masterly manner by their Bards. And even the favourite legends of Classic authors, familiar as they are in most cases to our early recollections, are in some respects a sealed book. The stories of Atys, of Adonis, of Pentheus, and the Bacchæ, which education and Religious prejudice appear to have rendered fascinating and even affecting subjects to the Greeks, convey no sort of interest to a modern reader. How then, it may be asked, do we derive that interest from sources apparently no less foreign to our daily habits and ideas, and as totally unconnected with our own History? The answer is plain. The Argonautic expedition exactly recalls the adventures, on field and flood, of the "mighty and unconquered Goths," the *Vikingr* and the *Berserkir*, who with all their ferocity and lawlessness, claim a considerable share in our ancestry. The Siege of Troy in almost every respect touches on our chivalrous associations, as well as on the home-felt passions common to every Age and climate. Hector, Diomede, Patroclus, and Sarpedon, in no wise differ from the true Knights of Charlemagne or the Round Table,

> Sweet in manners, fair in favour,
> Mild in temper, fierce in fight.

And even Achilles himself, both in his faults and his virtues, bears a strong likeness to the fiery and imperious Norman Baron, or the Grandee of the days of Don Pelayo. The labours of Hercules and Theseus are precisely those of good Knights-errant, and Scyron and Polyphemus are in every particular the discourteous Giants of a Fairy Tale.

Interest in Imaginary Beings.

As to the interest which arises from Imaginary Beings, unconnected as they may seem at first with Human fortunes and feelings, the question is in some degree answered already with reference to Shakspeare, whose forcible conceptions of the Immaterial, and whose intuitive knowledge of all the links of Thought and Association, are acknowledged as unrivalled. His Fairies were, long before the reign of Elizabeth, installed by household superstition as the Dryads and Penates of our Island; and even Ariel and Caliban seem founded on the traditionary conceptions of the friendly *Brownie* and the malignant *Duergar*. Nor is it too much to assert that in every instance, the Poet, even when launching into the remotest flights of fancy, in order to attain the end of his Art, must adhere to those subjects which directly or indirectly come home to the "business and bosoms" of his readers.

How far mere Imitation is a source of Poetical Pleasure.

It must be granted that the Pleasure communicated by Poetry arises in a subordinate degree, but no inconsiderable one, from the skilful imitation of things not necessarily interesting in themselves. Hence the whole merit of the Art has by some been conceived to exist in the Principle of correct imitation through the medium of language; substituting, as it were, a part for the whole. Imitation of any sort, indeed, is a Principle implanted in our nature for the purposes of Social life, and of Mental and Moral improvement: observable in the earliest stages of infancy, and secretly felt and acted on in all the stages of Human life. Added to which, the Pleasure felt originally in an end attainable by certain means, communicates itself by association to those means, whether they accomplish the end or not. As the Soldier delights in the sight and handling of good weapons, the Student in the very smell of scarce and old editions, and the Musician in dull and complicated harmonies, so will the practised Critic derive a Pleasure from the mere skilful mechanism of Poetry, whether applied or not to a subject in itself interesting. Independent of which, the perception of a difficulty surmounted constitutes a source of pleasure to Minds which have tried the same experiment, and can appreciate success in it. Not that Poetry can be said in this respect to stand on so advantageous a footing as Painting, an Art to which it is justly considered to bear a strong kindred analogy. For in the latter case, the desire of acquisition, as well as the Physical sense of sight, is gratified by the possession of a work of Art agreeable from its colouring, and constituting an exclusive property: and to represent even a mean object with tolerable fidelity, argues a degree of skill attainable only by practice. But, on the contrary, Verse indifferently constructed on an ordinary subject is little more than the exercise of the gift of Language, which we acquire in early childhood, and differs but little from the manner in which a clown would express the same thing in his ordinary prose: nor can any property exist in a production which, if it be worth it, may be carried away equally in the Minds of all. As to the mere imitation of sounds, a humbler department sometimes tempting to minor Poets, no one can expect to vie in this respect with the juggler or ventriloquist.

Imitation a main source of Comic interest.

It is perhaps in Comic subjects that mere faithful imitation is most successful. Here it is sufficient to suggest circumstances which appeal to those habits of trite jocularity so characteristic of large and crowded societies. The predisposition to ridicule exists so strongly in Mankind when assembled in large bodies, that a mere stupid catch-word has in many instances unaccountably made the fortune of a buffoon, and the entertainment of a whole metropolis. Hence it is obvious how by judicious imitation, a Poet may in such cases afford a mine of higher amusement, to the Minds of those who are prepared by every-day habit to catch at and enlarge upon his slight allusions. The recognition-scene in *Beppo*, for instance, simply and gravely states a series of ordinary facts and conversation, without any ostensible attempt at humour, but put in such a manner as to suggest the ludicrous and secret embarrassment of all parties; the effect consequently is irresistible. Of the same description is Horace's inimitable scene in the *Via Sacra*. A simple story is accurately told, but in such a style as to awaken the utmost degree of ludicrous contempt for the tormentor, and of fretful sympathy with the Poet interrupted in his reverie.

Not sufficient in serious Poetry.

In graver Poetry, however, mere imitation seldom pleases without some merit or dignity inherent in the subject itself. Virgil's commonest descriptions in the *Georgics* are pregnant either with rural beauty, or with those grand and fabulous allusions into which his imagination seems to break loose on every occasion, kindling as it were with every successive line.

Olli ardua cervix
Argutumque caput, &c.

Talis Amyclæi domitus Pollucis habenis
Cyllarus, et quorum Graii meminère Poetæ,
Martis equi bijuges, et magni currus Achillei.
Talis et ipse jubam cervice effudit equinâ
Conjugis adventu pernix Saturnus, et altum
Pelion hinnitu fugiens implevit acuto.

The three greater sources of Poetical Pleasure.

Admitting, however, that the mere skilful mechanism of Poetry may afford a source of gratification in itself as an imitative Art, distinct from its subject; and premising that it always ought to be studied as a means of giving due effect to that subject, we will next consider the sources of higher Pleasure which the Art has in view. These appear to be, 1st, Sympathy, either with the Poet himself, as expressing a feeling in his own person, or with the subject of that feeling as described by him. Hence our interest in descriptions of the different passions to which Mankind are subject, on a more particular discussion of which it is our purpose to enter hereafter.

1. Sympathy.

2. The Sublime and Beautiful.

2. The sense of the Sublime and Beautiful. How this arises from external objects creating either awe or pleasure, has been fully and luminously discussed by Burke. The impressions caused by such objects as simply described in themselves, cannot be said to have any reference to the Passions, if in the latter be implied a desire or an avoidance of some ulterior result. When, however, blended in a Story, they may excite sympathy by their connection with the feelings and fortunes of the persons experiencing their influence, as well as awake their own peculiar and independent effect, thus exciting both the Passions and the Imagination.

It may be doubted whether in all cases Fear, or at least the pleasurable modification of it, which constitutes the sense of the Sublime in Burke's acceptation, be a necessary ingredient. For instance, nothing can be a more sublime object than the Sun in a Spring morning, awakening all the powers of vegetation, and the hopes and exertions of countless millions of animated Beings; or than the Nile in full flood, enriching whole Nations by its overflow: both of them destined to last till the commencement of Eternity, as the mighty agents of the Author of all Good. In these instances, the admiration felt is both Physical, in reference to the power displayed on so stupendous a scale, and Moral, in the contemplation of the beneficence of purpose; but Fear has no share in the impression produced by such objects. On the contrary, when we behold a Thunderstorm, a Cataract, or a Comet, the impression of the Sublime which such objects create may be defined as Awe, rather than Admiration. These feelings, therefore, may be considered as different varieties of the effect produced on the Mind by the demonstration of vast power, or in other words, the sense of the Sublime.

Admiration, as applied thus to Physical objects, will generally be found to imply some sense of the Beautiful, as well as of the Sublime. Analogous to this, or rather perhaps similar, is our sense of the pure Moral Sublime; *viz.* the impression produced by great Human powers of any sort, devoted to just and beneficent purposes. The very names of Alfred, Timoleon, or Washington, if judiciously introduced in Poetry, bring with them a thousand visions of Moral Beauty and Power, which never can pall on the Imagination of Mankind. On the contrary, the contemplation of such characters as

Imagination to the Soul, or sensitive part of the Mind, and impressed with more or less vividness, according to our degree of approbation arising from the justness of the cause, and the due proportion which the effect, as expressed by the conduct of the person with whom we sympathize, appears in our eyes to bear to that cause.

It is needless to remark that the Sympathy thus felt with those persons with whom we meet in real life, is in every respect precisely the same with that which the Poet creates in favour of imaginary characters. We will now proceed to consider the different Passions as the sources of it; as well as to separate from them those affections or habits of the Mind, which are often inaccurately included under one common name.

General Definition of the Passions.

If we conceive the term *Passion* aright, it implies neither a permanent habit of any sort, nor a conviction of the Understanding; but rather an affection of the Heart, or sensitive part of the Soul, arising from a specific reason, and generally pursuing a specific end. Thus Anger arises from the perception of some particular injury, and seeks some particular retribution; Pity is produced by the contemplation of a specific calamity, which it impels us to relieve, and Terror by the show of some particular danger from which we instinctively fly. On the contrary, Hope may rather be considered as a pleasurable affection of the Intellect, than of the Feelings; Friendship, Ambition, and Melancholy, rather as habits predisposing us to the constant influence of certain kindred Passions, than as Passions in themselves; and the directly opposite feelings of Scorn and Admiration, as the verdict of our Moral and Thinking nature, justifying the exercise of the feelings by which they are accompanied almost inseparably. As to Laughter, though an involuntary and generally pleasant affection of the feelings, and arising always from a specific cause, it certainly cannot be styled a Passion, and in fact has hitherto so completely baffled definition, that we shall not attempt the task. It may be perhaps styled a titillation of the Understanding, excited by any unexpected incongruity, as a cough or a sneeze is caused by an obstruction of the bodily organs: and neither of necessity implying Scorn, Pleasure, or any other distinct purpose. Although, as we have stated, it be in most cases pleasurable, it has no reference to any thing which we covet as a good, or avoid as an evil. Joy and Sorrow may rather be considered as general characteristics belonging to all the different Passions, and synonymous to mental Pain and Pleasure, than as Passions in themselves.

Classification of them.

In attempting a classification of those affections more properly included under the name, it is obvious that the social and the resentful Passions, in the first place, stand directly opposed to one another. A general tendency to both should seem naturally implanted in the Mind of Man, so as equally to balance his own character and interests with the considerations due to others. Again there is another class of Passions founded on self-esteem, which may be considered as cooperating with either one or the other of these opposite Principles. We mean Triumph and Emulation, on the one hand, and their opposites, Shame and Remorse, on the other. And in fact so nearly are the Passions of the former class connected with the resentful Passions, that in most instances they originate them, when frustrated in their gratification; while on the contrary Shame and Remorse have an equal tendency in restoring the due balance of the social Passions, operating as they do as a corrective of selfishness.

Terror, and Love in its mixed sense, approach perhaps most nearly to merely Physical impulses. But when the former is felt for another individual, and the latter implies disinterested good will, they become social and generous Passions. And in general this rule may be laid down in reference to the Passions, that in proportion as they are connected with motives not merely selfish, so are they fitted to excite the sympathy of the reader, provided they are not disproportioned to their exciting cause.

Resentful Passions.

Anger and Indignation are the only Passions of the resentful sort adapted to create any sympathy with the person suffering them; and the former only as it approaches in any degree to the quality of the latter. For however loosely these terms are confounded in common conversation, Anger is a Passion purely selfish, Indignation is social and generous, inasmuch as, though impelling the Mind to precisely the same actions, and accompanied by the same outward marks, it proceeds from the sense of an injury done to others. To render Anger therefore touching and interesting, it must be represented as awakened by the sufferer's perception of justice outraged in his own person, and the apprehension of the loss of honour in the eyes of Society as judges of his actions. And in real fact, the sense of self-humiliation, or of disgrace is, as is justly remarked by Aristotle, a stronger ingredient in Anger than the loss of any more tangible advantage. Hence this Passion is in any case more creative of Sympathy than the rest of those which belong to self-love. To define it more accurately, it seems a painful desire of redress, not merely general, or consisting in any misfortune to the real or fancied injurer, but such redress as shall exactly apply to the point wherein the injury consists, and shall be avowedly exacted by the injured party:

φάσθαι, 'Οδυσσῆα πτολιπόρθιον.

εὖτ' ἂν πολλοὶ ὑφ' Ἕκτορος ἀνδροφόνοιο
Θνήσκοντες πίπτωσι, σὺ δ' ἔνδοθι θυμὸν ἀμύξεις
Χωόμενος, ὅτ' ἄριστον 'Αχαιῶν οὐδὲν ἔτισας.

I forg'd the letter, &c.
I hated, *I* despised, and *I* destroyed.

Revenge (as exemplified in the above passage from the Drama to which the Passion gives its name) is in reality only a more prolonged and bitter state of Anger, soured by the delay of the desired redress; and from its calculating and insidious nature, rather productive of detestation than of sympathy. It is, however, equally personal in the reparation which it seeks, and equally desirous that such reparation should be avowed and particular. Accordingly Zanga reserves himself for the moment when his Revenge can not only strike home, but speak out. The anonymous and secret malice of cowards proceeds exactly from a similar feeling, deprived of its full gratification by the conflicting motive of fear. Such appear to be the different degrees in the scale of resentment. The scene in the Ist Book of the *Iliad*, from which we have recently quoted, contains one of the noblest instances of the Passion, as dignified by circumstance and motive. The Anger of Achilles vents itself on the instant in an open and gallant defiance of his Suzerain in the plenitude of his power, without calculation of consequences. Seeing nothing but his wounded honour, and spurning away the ostensible cause of the quarrel as beneath the notice of a Chieftain, he proudly anticipates the future shame and confusion of his adversary in a taunt which evidently arises less from vain-glory, than from the reaction of his Soul to restore its own self-esteem.

In Mr. Lockhart's admirable translation of *Legendary Spanish Ballads*, a Work by no means so well known as it deserves to be, the Passion of Indignation is placed in its most touching and generous form, in the person of Bernardo del Carpio, a National hero in equal estimation with the Cid. The warrior is described as coming to the Court of King Alphonso, whose life he had saved at Roncesvalles, avowedly for the purpose—"the lying King to beard," with the breach of his word of honour in the murder of the Count de Saldanha, Bernardo's father. His demeanour while marching at the head of his twenty chosen Knights, is marked by a solemn and stern grief, which nothing but his bold purpose can alleviate. When received with curses and taunts by the suspicious King, he answers by a short summary of his services and their perfidious reward; and replies to the menaces of Alphonso by abjuring his allegiance sword in hand. We will commence our quotation with a part of the "Funeral," as an introduction to the scene before Alphonso.

He stoops him o'er his father's shroud,
  His lips salute the bier;
He communes with the corse aloud
  As if none else were near.

His right hand doth his sword unsheath,
  His left doth pluck his beard;
And while his liegemen held their breath,
  These were the words they heard;

Go up, go up, thou blessed ghost
  Into the arms of God;
Go, fear not lest revenge be lost,
  When Carpio's blood hath flow'd;

The steel that drank the blood of France,
  The arm thy foe that shielded,
Still, father, thirsts that burning lance,
  And still thy son can wield it.

* * * * *

A curse upon thee, said the King,
  Who com'st unbid to me,
But what from traitor's blood should spring,
  Save traitors like to thee?

* * * * *

The life of King Alphonso
  I sav'd at Roncesval,
Your words, Lord King, are recompense
  Abundant for it all.

Your horse was down, your hope was flown,
  I saw the faulchion shine,
That soon had drunk your royal blood
  Had I not ventur'd mine.

But memory soon of service done
  Deserteth the ingrate,
And ye've thank'd the son for life and crown
  By the father's bloody fate.

* * * * *

The King that swerveth from his word
  Hath stain'd his purple black;
No Spanish Lord will draw the sword
  Behind a liar's back;

But noble vengeance shall be mine,
  An open hate I'll show;
The King hath injur'd Carpio's line,
  And Bernard is his foe.

Seize, seize him! loud the King doth scream,
  There are a thousand here,
Let his foul blood this instant stream;
  What, caitiffs, do ye fear?

Seize, seize the traitor! but not one
  To move a finger dareth;
Bernardo standeth by the throne,
  And calm his sword he bareth.

He drew the faulchion from its sheath,
  And held it up on high;
And all the hall was still as death;
  Said Bernard, Here am I,

And here's the sword that owns no lord
  Excepting Heaven and me;
Fain would I know who dares his point,
  King, Conde, or Grandee."

Hatred. The Passion of Hatred, as Aristotle has defined it in opposition to Anger, a deep, inactive, settled desire of evil or destruction to a particular person, without any defined purpose, or longing after personal retribution, is, as we conceive, of very rare occurrence in real life. In this detestable and unmitigated form, it is plainly unsuited to the purpose of Poetry; as, on the one hand it is totally repulsive of sympathy, and on the other, from its quiescent nature, can neither serve as an active engine for forwarding the plot, nor for a means of creating terror.

Jealousy. Jealousy may be considered rather as a mixed Passion, although as to its operation and results, it classes most nearly with the resentful class of feelings. Strictly speaking, the term is capable of two meanings, inasmuch as it either implies the more or less vague apprehension of a mortal injury in Love or Ambition, or the sense of that injury as having occurred. As relating to Ambition, it seldom can be so treated as to inspire sympathy, and is employed rather as a component in those characters with whom the hero of the story has to contend. For here its operation is exclusively selfish. Not so of necessity, where the cause of Jealousy relates to Love. It is in the power of the Poet to create a strong sympathy for the jealous person, if he describes him as Othello, "of a constant, loving, noble nature;" his eyes either gradually opened to real infidelity, or blinded, as in the case of the Moor, by skilful and treacherous machinations. Here, and in all the instances in which this branch of Jealousy has been rendered touching, the reader is made to perceive that it is not so much the object of a sexual and selfish Passion that is regretted by the hero, as the pain of finding his unlimited affection and confidence returned by treachery, and the Being proved unworthy, on whom he had centered those feelings. The deceit practised on him makes no difference in the reader's sympathy with the revulsion experienced by a generous mind, and the sense of injustice naturally felt. But to preserve this sympathy unimpaired, the Dramatist has judiciously made nothing to arise from the active impulses of Othello's suspicion, and every thing from the art of Iago. Self-creating Jealousy is totally unfit to establish any interest for the party by whom it is felt; for although in real life it is a common and grievous calamity, it is confessedly peculiar to weak servile dispositions.

Envy. It is difficult to distinguish Envy from the branch of Jealousy applicable to Ambition; unless indeed it may be said to be more malignant as well as more passive, and less accompanied by Hope, Enterprise, or Rivalry; a sort of impotent instinct, as it were, unconnected with any definite project. It is needless to say, that this is a feeling utterly incapable of creating sympathy under any circumstances, and only to be interwoven in those characters destined to forward certain parts of the under plot, inasmuch as it implies a want of power inconsistent with the energies of a principal villain.

The character of those Passions to which we have hitherto adverted is decidedly painful, although they are directed to the attainment of a pleasure more or less vague or practicable. That of the gentler or more Social Passions is, in most instances, pleasurable; and in all, somewhat tempered by pleasure.

Love, in a general sense.

Love, in its sense of ardent and disinterested good-will, is the noblest and the most comprehensive of all the Social Passions. Its branches may be distinguished thus: Gratitude, or Love occasioned by benefits received. Benevolence, or the good-will extending itself to all creatures capable of pleasure or pain; and thirdly, Social Love, either of Country, parents, friends, relatives, or mistress. It is obvious that many of the branches of Social Love may be partly compounded of Gratitude, or that modification of it arising from the interchange of benefits: and that the Love of the Deity consists in the pure and overpowering sense of Gratitude to an incomprehensible Being whom we only can feel and behold through the medium of his benefits.

Pity and Regret.

Pity and Regret may be considered as Passions equally Social; and although rather modifications of Sorrow from causes connected with Benevolence, Friendship, or Natural affection, are in every stage attended with a certain generous and satisfactory expansion of the Mind, and in some stages, with a feeling somewhat allied to pleasure. We speak not of Regret when combined with Remorse, in which state it frequently exists, and as such, is calculated to excite the most profound sympathy. Pity again may be defined as rather existing in the mind of the reader when excited by circumstances of sorrow, than felt as a sympathy with an imaginary personage, as in the case of Anger or Terror.

To resume the subject of Love, it appears that no branch of it requires definition or distinction, save that which in common parlance is called by the name. It is clear how well fitted for the purposes of Poetry, and how productive of sympathy, as well as abounding in Moral beauty and sublimity, are the varieties of Love in a General and Social sense, which are comprised under Patriotism, Natural affection, Gratitude, and Friendship, and how many of the finest episodes of Poetry are founded on the heroism which these naturally produce.

Love between the Sexes.

With respect, however, to Sexual Love, (there being no other precise term by which to designate the feeling,) it is plainly alloyed more or less, even in its purest shape, with a degree of selfish and animal desire. Yet since, as experience teaches us, none of the higher Social Passions are more influential in producing noble and disinterested actions, none also are more fit to become dignified subjects of Poetry, and to create sympathy, than that more refined branch of it, which we may style the Sponsal and Heroic. Such, for instance, as is exemplified in the touching episodes of Orpheus, Hœmon, Alcestis, and a thousand others of ancient and modern invention, where the Passion is clothed with all the tenderness which characterises the relation of the sexes, and at the same time made triumphant over danger, death, and fate.

It was probably this higher degree of the honest and intelligible earthly Passion, and not any Metaphysical vision, which the Ancients contemplated under the name of Venus Urania, or, as we may fairly translate it, Heroic Love: and, indeed, their experience in their own Literature might well warrant the distinction. The lowest form under which the mere mundane Passion is exhibited, is in the incestuous and beastly episodes of Ovid; and less disgustingly, though more weakly, in the whole mass of that Poetry which passes under the name of the Amative and Pastoral. In the latter style, now happily exploded, it is easily perceived how utterly devoid of interest and sympathy mere Love becomes, when stripped of nobler accompaniments. Damon or Strephon, complaining of a richer or more comely rival, and with nothing to plead but the waste of intense desire and tuneful wind, excites no higher species of compassion than would his favourite bull, if expelled from his walk by some other horned Tarquin of the village; for the nature of the disappointment is precisely the same in man and beast. Accordingly the Poet finds it a necessary part of his practice to assist the Lover with the always ready sympathy of Pan and the Dryads, the leaves, the flowers, and the faithful dog, and such other frigid tritenesses.

Amative Poetry.

Love, as treated by the Euphuists.

The contrary extreme in style is of modern growth, and apparently derived from those Troubadours, who were admitted as assessors in the Provençal Courts of Love, held gravely by Queens and Princesses. The deification of the Fair sex was certainly graced and redeemed from much of its absurdity, by the loyal and heroic actions to which it appears at first sight to have instigated the hardy Barons and Chevaliers of the Dark Ages; bearing, as it does, a tinge of the Religious veneration in which Tacitus describes women to have been held by the ancient Germans. But, as in many other cases where the means afford the real satisfaction, and the ostensible end is but secondary, so it is probable that, in many instances, the name and sanction of a mistress was assumed, to justify the indulgence of a high-flown spirit of Knight-errantry. Nothing therefore could be more cold and meagre, when abstracted from the stirring legends of flood and field, Cross and Crescent, Paladin and Paynim, than such Love as this. The Euphuistic and Metaphysical School of Amatory Poets, who may be said, perhaps, to have commenced with Petrarch, and ended with Cowley, adhered perseveringly to the same warped and absurd view of the Passion, when the circumstances which dignified it were past by. If we may be allowed the metaphor, they stripped the Gothic Cupid of the Baronial armour which had dignified his puny form, and plastered the forked stick which remained, with an ingenious coat of tinsel, while they mounted it on an eminence even loftier than before. It is needless to say, that Modern taste, particularly as exemplified in our Popular Romances, is in this respect improved into the right medium. The style of the Ancients, and their conception of Love, is in general perhaps too nearly allied to the sensual, though many instances to be found in the Greek Poets prove that they abounded with loftier views of the subject. Among those of the Latin School, Virgil perhaps stands alone in what we may call the mixed mode. The episode of Dido, though not in every respect accordant with our notions of delicacy, abounds in all the higher and more pathetic Passions of Tragedy. The character of the hero, as drawn from his own unconscious narrative, appears to warrant her devotion. Like Desdemona,

> She loves him for the dangers he has past.

And the *multa viri virtus, multusque gentis honos*, is judiciously thrown in by the Poet as the first commencement of her Passion.

The Works of Catullus, and others of his class, however abounding in Poetical genius, display the merely grosser part of the sentiment, and stand in almost a ridiculous contrast to the Euphuistic School, nor is there much apparent chance that either offensive extreme will again become popular among cultivated readers. The true medium, by the adoption of which the Passion can be made to awaken sympathy, appears to us to consist in this. In the first place, either a requital, or the fair chance of a requital, should be shown, as a sufficient cause is necessary to warrant sympathy in the spectator. Next, a tone of warmth is required to give it life and reality; but this, to speak by analogy, should be the vivifying warmth of the Sun, imparting vigour and solidity to the oak which is destined to stand a thousand storms, not the gross kitchen fire of Eumæus, melting away the substance of the hog who roasts passively before it, nor the cold light of the Moon, the presiding Genius of Metaphysical and fanciful Love.

True Love.

ity.

To resume the subject of Pity, a Passion which has been pronounced akin to Love, we recognise the justness of Aristotle's rule, that it can only apply to undeserved suffering; for even in those real or imaginary cases where guilt is punished, the portion of Pity which may be felt proceeds from an involuntary impression that the punishment exceeds the demerit. In real life our senses are still more struck by the sight of the actual suffering, and our sense of the crime remains for the time in abeyance; but as this cannot be equally the case in fiction, Pity can only be created here for objects more or less undeserving of sorrow.

The Pity of practical life is so frequently alloyed by officiousness, curiosity, and even by the baser motives of triumph and self-congratulation, that it passes with many persons as the synonyme for Contempt, and is even more deprecated than aversion. Nevertheless, when pure, it is a sympathy equally "honoured in the giving and receiving," even towards an Alfred or an Aristides. It is heightened in reality, and of course is capable of being additionally heightened in fiction, by the firmness and heroism of the party under affliction, as well as by his previous deserts. Œdipus at Colonus, though a beggar and an outcast, appears in the hands of Sophocles with much more real pathos and dignity, weary of life, purified by misfortune, and viewing with the steady eye of prophecy the destiny he has come to encounter, than Œdipus on the throne.

It may be remarked also of the Tragedy bearing the latter name, (more perfect perhaps in its gradual and concise developement than any Play, ancient or modern,) that the attention of the spectator is judiciously diverted from dwelling too minutely on the crime when discovered, by the punishment which the guilty, or rather the ill-fated parties instantly inflict on themselves. The self-retribution exceeds the guilt of the unconscious crime, and at the same time argues a strong sense of piety and honour in those inflicting it, and thus the full measure of Pity is preserved even under circumstances of a revolting nature.

dotes
ty.

The circumstance of ignominious punishment unaccompanied by death, even when undeserved, is obviously unfit to create Poetic sympathy, though nothing can really be more bitter, and more strictly pitiable. But this no one can apply in imagination to his own case without a feeling of shame and disgust; and no one has therefore learned to contemplate it as a familiar subject of sympathy. Wallace, with the fatal cord round his neck, though in the situation of the lowest criminal, is a sublime and touching object; but had Wallace been whipped and dismissed, the punishment, though a thousand times greater to a hero, would have precluded the sort of Pity felt for a hero's misfortunes.

Nor again ought pitiable circumstances to be of too hopeless or horrible a sort. It should seem, that as the only pleasure felt in the exercise of compassion arises from the alleviation which the spectator proposes to afford, or the reader foresees, and imagines himself affording; so in either case, when the misfortune exceeds the possibility of aid, we give it up in despair, and wish to divest our minds of the impression. Thus far of those branches of misfortune which Aristotle comprises under the name of τὸ μιαρὸν, are improper for the subject of Poetry.

Madness as a subject of Pity.

That Madness should be, as it is, a powerful source of pathos, may seem inconsistent with the preceding remarks, as well as with the view which we have taken, in accordance with Adam Smith, of the nature of Sympathy. The difficulty may perhaps be solved thus. Were a faithful picture afforded of the ravings of an incurable Madman, alleviated by no lucid intervals, and varied by no recollections of his former state, it would exactly come under the predicament of the μιαρὸν, and excite no interest. All Poets of judgment, therefore, in the treatment of this subject, have chosen those mixed and common cases, in which the patient retains sufficient consciousness to lament over the wreck of himself, and foresee the coming paroxysm of his disorder; or where, in his wildest frenzies, he is still haunted with the distinct and bitter sense of the exciting cause. The instances to which we allude are those of Lear and Orestes; in both of whom there remains sufficient of sanity to enable the spectator to invest himself with their feelings. And no situation can be productive of more touching sympathy, than that of

> Love watching madness with unalterable mien,

the patience and devotion of such characters as Cordelia, Electra, the faithful Pylades, and the noble Kent; their painful recollections of what the sufferer was, their shuddering perception of what he is, and their unwearied efforts to alleviate his situation.

Concentration of Pity.

To afford the Passion of Pity its free and natural exercise in the mind of the reader, it ought to be concentrated on one object at a time, and that object should be characterised in a manner which may make it familiar to the imagination. Otherwise, as in fact takes place in real life, the sensation of Pity is weakened by diffusion among a number of individuals. We cannot illustrate this truth better than by employing the analogy of Historical Painting, in reference to the different ways in which the Massacre of the Innocents has been treated. The majority of Painters have exhibited their powers of grouping and contrast by encumbering the foreground with great masses of figures in every attitude, which, though they undoubtedly display the technical powers of the Art, perplex the eye and the Mind, and leave no leading object of compassion for either to rest upon. A modern French Painter, with a juster conception of the master feeling connected with this subject, has thrown the tumult of pursuit and massacre into distant perspective, and directed the eye exclusively to a young female cowering with her infant under the shelter of a ruined wall in the fore-ground, and listening with the most intense expression of horror to the footsteps of a murderer who is seen in the middle distance approaching the very spot. To instance a parallel example in the Drama, the simple plots of *Antigone* or *Alcestis*, turning on the fate of one touching character, create infinitely more sympathy than the mass of incidents and calamities crowded together in the *Phœnissæ*, a Drama nevertheless abounding in Tragic dignity and spirit, and second to no extant Work of Euripides.

Regret.

Regret naturally comes next in the order of Social Passions, as compounded equally of Love and Pity; or consisting perhaps in the sense of privation of an object of Love; a Social pain exactly in the degree in which Love is a Social pleasure. As its nature is to dwell on minute and trivial circumstances connected with its object, great judgment is therefore required in the Poetical selection of these, so as not to lower the dignity of the Passion in preserving its natural tone. In the expression of Regret also, as indeed of every other Passion, a degree of moderation and apparent self-command should be visible in the real or imaginary mourner; and the merits of the dead should rather be dwelt on, than the keenness of his own grief, in order to justify the cause of it to the reader and spectator. The *Æneid* perhaps contains no passage of greater Epic dignity and feeling, than that in which Æneas bids a last farewell to the bier of Pallas. In the studied military pomp of the whole ceremonial,

solatia luctus
Exigua ingentis, misero sed debita patri,—

and in the set and solemn invocation to the young hero's shade,

Salve æternum mihi, maxime Palla,
Æternumque Vale,—

there is a still stronger pathos than in his first burst of regret at beholding the body. We witness the deep feeling and deeper self-command of a stern and sage Leader, repressing such acts and expressions of sorrow as might unman him on the brink of action, and indulging the proud consolation of blending his youthful friend with the memory of Hector, Sarpedon, and his other departed comrades in a hundred fights.

To our apprehension indeed, "the tears of bearded men," when judiciously introduced, are a more powerful source of sympathy than those of women and young persons, to whose circumstances such expressions of emotion are more suitable. There is a stronger contrast, and, as it were, a greater force from previous compression, in the grief of a stern and powerful mind, bursting forth in spite of a degree of restraint proportioned to the magnitude of the cause: and in the circumstances under which alone such grief can appear natural, there is usually nothing of the every-day selfishness of sorrow. In the last Book of the *Iliad*, it is true Achilles weeps as bitterly as a woman or child, but his tears are shed in the solitude of his tent, and under circumstances which redeem them. The hero, sleepless after the fatigue of gigantic feats of strength and daring, and inconsolable amid the applause and gratitude of leagued Nations, sees and feels nothing but the depth of his own abandonment; and (which shows the highest judgment in the Poet) his sorrow arises not from the mere trivial and endearing recollections of Social life, but from the thought of the tried fidelity of his comrade in danger and privation, and their companionship in noble achievements.

Ἠδ᾽ ὁπόσα τολύπευσε σὺν αὐτῷ καὶ πάθεν ἄλγεα
Ἀνδρῶν τέ πτολέμους, ἀλεγεινά τε κύματα πείρων.

The same train of thought is admirably touched in *Don Ferdinand's Lament for his Brother*, a smaller Poem by an Authoress, perhaps unrivalled in giving a chivalrous grace to the tenderer feelings.

In the desert, in the battle,
In the ocean-tempest's wrath,
We stood together side by side,
One hope was ours, one path.
Thou hast wrapt me in thy soldier's cloak,
Thou hast fenc'd me with thy breast,
Thou hast watch'd beside my couch of pain,
Oh, bravest heart, and best!

Elegy and Epitaph.

As Regret forms the basis of Elegiac Poetry, it may be as well to comprise in this place the few remarks which we are led to make on that branch of the Art. The desire to rescue the virtues of a friend from oblivion is so powerful and natural, that it has impelled many writers into eulogies destructive of the sympathy of the reader by their fulsomeness, however sincere, and out of character with the sacred repose of the grave. The mourner loses his character as such by becoming an ambitious Orator; and we safely leave him to the consolations of the sort of secondary egotism which he has evinced. If any thing, on the contrary, be sure to excite the sympathy of Beings who feel themselves rolling along like atoms in the tide of eternity, it is a short mention, and little more, of name and date, as the modest appeal from the utter forgetfulness of the tomb, in behalf of those who once lived, suffered, and enjoyed like themselves; and if the occasion can warrant any posthumous praise, it should be covertly implied in some short and pithy expression of deep grief, which never can be out of place. Lest we should appear to confound the subjects of Elegy and Epitaph,* be it remarked, that the purpose and leading sentiment of both being in every case the same, the same rules, with a very trifling latitude, apply to both. In the expression of the bitter and enduring grief which "sorroweth without hope" in contemplating an everlasting separation, the Ancients, to whom such feelings were natural, will probably never be excelled. There is a brevity, and a solemn simplicity in the "Χρηστὲ, χαῖρε," the "*Eheu Unica!*"—and many of those monumental inscriptions which they have left us, contrasting singularly with the stiff emblazonries of arms, and the enumeration of a hundred real or imaginary virtues, which perpetuate the bad and worldly taste of the last two Centuries, and make the memory of many an obscure and respectable person absurd. If we may be allowed a fanciful allusion, it seems that the tone of such tributes should be in keeping with the solemn devotional strain of the *De Profundis;* an appeal, as it were, from the power of the grave to Him who saith, "I am the resurrection and the life." The short and touching N. M. *Implora pace*, or *Orate pro animâ*, of foreign churches, the simple text on a village grave, breathing humble Religious confidence, and the defaced effigy of the Crusader folding his hands in prayer, and as it were bowing his

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* *MARIANNÆ S——*
Conjugi nunquam satis plorandæ
Inane hoc, tamen ultimum
Amoris consecrat testimonium
Maritus, heu! superstes.

The above Epitaph, inscribed on a plain marble tablet in a village church near Bath, is one of the few in which the Latin Language has been employed with the brief and profound pathos of ancient sepulchral inscriptions. As a parallel instance in Elegy, we may mention the well-known six lines consecrated by Bishop Lowth to his daughter's memory.

mailed strength to the Power that made him; all these, different as they may be in their outward character, appear to us appropriate symbols of the calm unearthly mood which gives to Elegy or Epitaph its most powerful effect in a Christian Country.

A loftier tone may be allowed in the commemoration of those public services which appeal to the gratitude of posterity; though even here, the true impression conveyed to the mind of the passer-by should be the hope that the soul of the Patriot, Hero, or Statesman may the rather find rest in behalf of the services rendered to his Country, and of the greater temptations to which his commanding situation has exposed him. Yet in such cases the virtue of brevity is as necessary, though for different reasons, as in the memorials of private affection. Not a word was inscribed on the Colossal Lion placed upon the plain of Platæa. The same noble conception was adopted in that cut out of the solid rock in Swisserland, to the memory of the *Cent Suisses*, marked only by the shield of France, and the inscription

Helvetiorum fidei et virtuti.

A feeling exactly similar prevails in the Epitaph attributed to Simonides, on Leonidas and his three hundred warriors; a soldier-like distich, to which invention and imagination could have added nothing which would not have derogated from its Laconic dignity.

Ω ξεῖν', ἄγγειλον Λακεδαιμονίοις ὅτι τῇδε
Κείμεθα, τοῖς κείνων ῥήμασι πειθόμενοι.

Thus the mere name of Washington, Nelson, or Sobieski, would speak volumes to the recollections of the passer-by, without the addition even of a word or a date. Even the rough stone of Lützen* is more eloquent than the most elaborate inscription.

We have now to speak of those Passions which are founded on the sense of self-esteem and the reverse, and which are connected with those of the Social sort, as cooperative with them, or the contrary.

de and ity.

Both Pride and Vanity are terms loosely used, as implying either the pleasurable sense of self-esteem resulting from a comparison of ourselves with others in trifling or in great things, or the earnest desire to obtain such advantages as may justify that sense in the eyes of others: a desire which, when seconded by action, assumes the name of Ambition; and which, although used in reference both to important and to trivial objects, is usually applied to the former. The term Pride is also more commonly used to denote the calm consciousness, well or ill founded, of great advantages, as that of Vanity applies to smaller distinctions, and a more restless and agitative state of mind. The former is a *defensive*, the latter an *aggressive* mode of self-esteem. As, however, it is difficult to draw the exact line between the two Passions, and as Ambition seems to denote a permanent habit of the Mind, we may be allowed to simplify the subject by calling the general desire of distinction, Emulation, and the sense of its gratification, Triumph. Neither of these Passions, though useful in producing incidents, and imparting a sort of stage effect to particular conjunctures of the story, are in themselves productive of sympathy, as being exclusively selfish, and in their nature apt to exceed the bounds of moderation, as in Theocritus's picture of the delighted clown:

ation ri-

Ἰδ' ὡς μέγα τοῦτο καχαξῶ
Καττῶ Λάκωνος τῶ ποιμένος.

When indeed the emulation is of a dignified nature, and exerted in a generous manner, it may well become the object of sympathy; but in that case it is not so much the feeling itself with which we sympathize, as those higher impulses which purify, control, or excite it; as in the single combats of Chivalry, fought according to all honourable rules of war and courtesy, for the glory of Liege or Mistress; or in the challenge between Glaucus and Sarpedon, the termination of which furnishes so agreeable an episode in the *Iliad*. A similar rule applies to Triumph. In the Legend of Bernardo del Carpio already quoted, the hero, whose Triumph is certainly most complete, claims the sympathy of the reader as a son and a warrior, asserting the honour of his dead father and himself at the risk of his life, and branding the ungrateful Monarch with infamy in the face of his Court. But here, again, the feelings with which our sympathy moves in accordance, are the sense of filial devotion and of honourable resentment, not the mere sense of Triumph, which in fact is obviously a secondary object with the chieftain himself.

Scorn, of the Satirical sort.

The sensation of Scorn, in its purest and most unmixed sense, we conceive to be more a calm mental impression than a Passion; unmingled as it is with any pleasurable sense of triumph or comparison, and in itself implying no ulterior desire or object. The most complete instance of it is embodied in Goëthe's wonderful conception of Mephistopheles, the only real and unmixed Evil Spirit in the History of Poetry. The Demon appears to sit on a lofty and cold eminence, like the Genius of a glacier, looking with a freezing glance at the Passions and projects of the human atoms moving below him, and "grinning a ghastly smile" to see their bones whitening in the crevices of his domain. To take a more familiar instance, the feeling with which the Ox in Æsop's Fable is supposed to regard the emulous Frog, is a Scorn the more intense, because it is indolent and impassive, condescending to no comparison, and accompanied neither by Resentment nor Triumph.

The discriminating knowledge and application of true Scorn appears to have been one of the secrets of the power and dignity of the ancient Satirists. On the contrary, much of the effect of more recent Satirical works is weakened by the mixture of more contentious elements. The demonstration of the personal feelings of Anger, Jealousy, and Triumph, causes much of Churchill's powerful venom to recoil upon himself, or fall harmlessly to the ground. Again, in Lord Byron's Satire, *English Bards and Scots Reviewers*, the mortified and exasperated air which the author cannot conceal in any part of its course, is the reverse of that apparent sense of contemptuous superiority, in which the bitterest sting of Satire consists. He flourishes a horsewhip, as it were, furiously in the face of the world, leaping and shouting at the anticipated success of every hit. Instead of calling to the reader, "Ned, prythee come out of that fat room, and lend me a hand to laugh a little;" he cries, "Gregory, stand by me, and remember thy swashing blow;" an appeal effective only when addressed to a partisan.

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* A rude boundary-stone, close to which Gustavus Adolphus fell, is pointed out with religious veneration by the peasantry on the plain of Lützen, and known by a peculiar name.

The *Dunciad* of Pope, on the contrary, is marked throughout by a careless consciousness of power exerted for his own sport, like that of a cat tormenting a mouse, which must have been doubly galling to those whom he assailed. He seems like the very Genius of Scorn descending from his eminence, to relax himself with the exercise of the knout, rather than an angry mortal, fighting his way vigorously, like Byron, through a crowd; or like Churchill, shovelling mud at all who oppose him. In the scale of those who have succeeded in embodying the true and genuine conception of the feeling in question, Juvenal may be said to represent the Penseroso, and Pope the Allegro.

Scorn, as embodied in Narrative Poetry.

As adapted, however, for Narrative and Dramatic purposes, Scorn assumes a more mixed and active form, and may fairly be called a Passion. It is obvious that the mere expression of that calm impassive contempt which imparts to Satire its bitterest sting, contributes in no way to the furtherance of a plot; and that for this purpose it must be combined with action and event. Nor can this in any way take place, excepting in the shape of Anger or Indignation; that is, Resentment for Scorn done to ourselves or to others. In the overt acts therefore to which these Passions are made to give rise, Scorn may be considered as the secondary emotion, whose expression by word or deed tends to gratify the leading one of Resentment.

There is perhaps no passage in Poetry more expressive of the most sovereign degree of resentful Scorn, than the reply of Angiolina to Michael Steno, in the *Doge of Venice*. Yet even here the mixture of personal feeling in an insulted and high-minded woman, (expressed perhaps rather too wordily,) which is necessary to give a natural effect to her words, imparts a quality to the Passion in question very distinct from that of the pure Contempt which it has been our study to point out as the essence of Satire. Admiration, which in different ways is the converse both of self-esteem and of Scorn, is, as we have stated, rather in its general sense an affection of the Understanding than of the heart; inasmuch as it may arise from the contemplation of any wonderful scientific or mechanical work, or even any remarkable feat of strength and agility, the success of which may not interest us. As a source of Poetical pleasure, it resolves itself either into the sense of the Physical and Moral sublime of which we have treated, or into the Social Passion of disinterested Gratitude excited in some one or more imaginary personages by the great and worthy deeds of another. In the latter form, though eminently fitted to excite the sympathy of the reader, it addresses itself directly to his Mind without requiring the medium of any character with whom to sympathize, and without alteration of its quality. Though one of the most exalted of the Social Passions, it is that which has least to do with the conduct and developement of a Narrative Poem, being rather known as a final effect than as a cause.

Shame and Remorse.

Shame and Remorse, though in their nature resulting from culpable or humiliating circumstances, are in themselves Passions more indicative of the Social and Moral nature of Man, than those to which they stand opposed as negations of self-esteem; and when judiciously treated, excite a more complete sympathy. While Emulation and Triumph are founded in selfishness, these, on the contrary, are the results of the operation of conscience. Though in many cases they are combined, and very similar in their workings, Remorse may be defined as a pain more approaching to Pity, and accompanied with the desire of reparation to an individual; while Shame, on the contrary, is the painful sense of that which has forfeited the esteem of ourselves, or of the World in general; as exemplified by the respective feelings of Alexander on the murder of Clytus, and of the survivor of the three hundred Spartans, when devoting himself at Platæa. Both these are instances of the self-reproach of noble minds, operating from different causes, and equally productive in both cases of sympathy. And Shame may be said to mingle itself with Remorse in the degree in which the individual has forfeited his self-esteem by the act of injury in question.

In the motto prefixed to Coleridge's Drama of *Remorse*, the Poet defines clearly that which we consider as the only true form of the Passion, while at the same time he assumes as the basis of his plot a feeling more allied to the intolerable sense of Shame in a haughty spirit, gradually exasperated into resentment against the innocent cause of that Shame. The character of Ordonio, though powerfully drawn, is perhaps too bold an attempt to embody an anomaly in Human Nature, such as rarely occurs, and from its uncommon and antisocial tendency, the object of no sympathy.

We may contrast with this false Remorse the mutual self-abasement of two honourable minds, which is rendered so touching in the reconciliation of Pierre and Jaffier upon the scaffold; the one humbled to the dust by the sense of his former treachery, the other haunted in his last moments by the self-recoiling Shame of "the filthy blow his Passion dealt," and anxious not only to testify his own forgiveness, but to soothe his friend's sense of personal indignity. The sympathy of the spectator is here of a higher nature, knowing them both as men of haughty spirits, from whom neither Fear nor selfish feeling could have extorted one word of deprecation.

Though deep Remorse may evince itself in a general ferocity and recklessness of character, (and so far the character of Ordonio seems natural,) we still doubt whether it be consistent with ill-will towards the injured person. In fact, the vulgar dogma that men hate those whom they have injured, applies to morbid Pride, or the abject Fear of retaliation, and not to the sense of Remorse, in its proper meaning. It may even be doubted whether in all real cases, Remorse does not mingle with regret for the dead, suggesting all forgotten instances of slight omissions or unkindness. And in the grief of Admetus, Orpheus, or Achilles, as the subjects of ancient fable, there is blended a strong tinge of this self-reproaching Passion, arising from causes distinct enough to justify it, yet not sufficiently culpable to abate the reader's sympathy. Thus also the allusion to the death of Major Howard, in *Childe Harold*, derives a greater grace and pathos from the slight glance at a repented family feud:

Yet one I would select from that proud throng,
Partly because they blend me with his line,
And partly that I did his sire some wrong,
And partly that bright names will hallow song.

We have dwelt more largely on the causes and the operation of the different Passions, as well as on their distinctive marks, because, either as felt or acted upon, they contain the History of Human existence, and of all the causes which influence it for good and evil, as well as the substance of all the genuine materials for Poetry. For without Human Action and Passion, the contemplation of the most sublime and beautiful Physical objects soon grows tedious and uninteresting; or rather their influence is only felt through the medium of the pain or pleasure which forms the basis of Human Passions. Milton's description of Paradise derives its principal charm from the tenancy of our first parents, in company with whom, as it were, the reader expatiates over its

> hill and valley, fountain and fresh shade,
> Made vocal by their song.

The magnificent picture of a storm which occurs in the *Georgics*, addresses itself to the Imagination as connected with the awe and peril of Man, and the vengeance of the fabled Jupiter; without which vivifying circumstances, all else would, in fact, be on a footing with the phenomena of an uninhabited planet.

> *Ipse Pater, mediâ nimborum in nocte, coruscâ*
> *Fulmina molitur dextrâ, quo maxima motu*
> *Terra tremit; fugêre feræ, et mortalia corda*
> *Per gentes humilis stravit pavor; ille flagranti*
> *Aut Atho, aut Rhodopen, aut alta Ceraunia telo*
> *Dejicit; ingeminant Austri, et densissimus imber;*
> *Nunc nemora ingenti vento, nunc littora plangunt.*

eneral emarks n the assions.

We have already enumerated the three ways in which the Passions become the sources of Poetical pleasure; either as productive of sympathy in the reader, or as a source of Moral grandeur, or, thirdly, as furnishing, by their effects, those vicissitudes and obstructions in the course of the plot, which when overcome, give a greater zest to our sense of Poetical justice, and which our Imagination delights to triumph over by anticipation. It is needless to enlarge on the union of Sensibility and Invention, of Moral tact and Metaphysical accuracy, which is required to exhibit on an extensive scale, the reciprocal workings of these main-springs of the Human Mind, balanced and selected in such a manner as to form a grand and harmonious whole, which may impress itself on the Imagination with the force of reality. Hence the rare attainment of excellence in the Epic or Tragic styles of Poetry.

The expression of one or two insulated Passions has often been successfully embodied in shorter pieces, where the Poet has copied faithfully the prevailing mood of his own Mind; but this faculty, compared with the master-power to which we have alluded, is as the operations of a small detached force, as contrasted with the combinations of an extensive campaign, or the melody of a single instrument in comparison with the perfect and well-arranged harmony of a whole orchestra.

We have endeavoured to trace a few main lines of separation and distinction in a field which is nearly boundless, comprising, as it does, the sum and substance of all which gives Poetry its true vivifying spirit. The most leading of these differences appears to lie between the selfish and the Social Passions, as repelling or exciting the sympathy of the reader and spectator in the proportion in which the Principle of self predominates or is forgotten; and as usually tending to produce evil or good, according to that proportion, though not universally so. Thus, as a general rule, Envy is a more mischievous Passion to Society than Anger arising from a justifiable cause. But the latter, even when its consequences are dangerous or pernicious, is calculated to excite some degree of the sympathy which the former, though powerless and suppressed, cannot command; the one being totally selfish, the other so far social as it is founded on the supposed loss of the esteem of our fellow-men. Thus also Ambition, when confined to the selfish desire of aggrandizement, excites no sympathy; when felt, as by the Olympic athletes, in the character of sons, lovers, or townsmen, it assumes a shape modified by other generous and Social Passions, and therefore highly interesting; though in the first instance, Society may reap practical good, and in the latter, contusions and deaths may be the only result.

It is hardly necessary to remark, that whether the Passion described be of the interesting or the repulsive sort, it must be in a manner toned down to that level which may meet the perceptions of readers in general, and preserve the laws of unity and keeping in the imaginary character to which it is attributed. Yet nothing is more common than the species of egotism which leads a writer to assign an undue preponderance to that Passion which his own mental habits best enable him to comprehend and enlarge on. Hence either the leading character is an exaggerated caricature, like a creature overbalanced by one disproportionate limb, or a tinge of sameness is imparted to the whole texture of the plot and the *Dramatis Personæ*.

Another snare is apt to arise from the ambition to create some novel and striking combination of Passions, such as may in reality arise at particular crises of events. Here the Poet, from the superior facilities afforded by Language, has certainly the advantage over the Painter, whose Art is limited to outward marks of Passion, and can embrace only one particular moment of time. In the same proportion, however, greater is the danger of the former being misled into incongruities, while he studies to avoid triteness,

> *et varias inducere plumas*
> *Undique collectis membris, ut turpiter atrum*
> *Desinat in piscem mulier formosa supernè.*

It is, for instance, a very common fallacy to imagine that Passions which take place in the order of cause and effect, are simultaneous; as for instance Fear and Anger, the latter being a very common reaction of the former, but superseding it as soon as itself exists.

The effects or workings of a Passion ought also never to be described by the person who is supposed to feel it, but should appear rather through the medium of involuntary words or actions: for it stands to reason that the Mind has not leisure to feel intensely and speculate acutely on the same subject and at the same moment. The forced and unnatural effect of Seneca's Dramas does not, perhaps, so much arise from the incongruity of the sentiments which the characters express, as from their reflective loquacity, "in the very tempest, heat, and as it were whirlwind of their Passion." Their chief object appears to verify and note down a series of phrenological experiments upon themselves, as minutely and absurdly as Io is described by Æschylus expatiating on her fit of epilepsy at the moment of its access, instead of leaving the office to the friendly Nereids:

> Τροχοδινεῖται δ' ὄμμαθ' ἰλίγδην,
> Ἔξω δὲ δρόμου φέρομαι, λύσσης
> Πνεύματι μάργῳ, γλώσσης ἀκρατής·
> Θολεραὶ δὲ λόγοι παίουσ' εἰκῆ
> Στυγνῆς πρὸς κύμασιν ἄτης.

The English taste, at the end of the XVIth and beginning of the XVIIth century, was replete with this sort of frigid Metaphysics, which for a long time were considered the finest and most courtly style of writing.

In no case indeed ought Passion ever to be made rhetorical, although in many its natural effect is to be highly eloquent. Euripides, than whom no writer perhaps has shown himself a more consummate master of the Passions, still appears to labour under a constant temptation to forensic effect. His controversy between Eteocles and Polynices, for instance, meeting as they do under feelings of furious excitement, is conducted as gravely and methodically as in a Court of law; its set phrase destroying much of the effect of the thought and eloquence to which a more natural form of delivery would have done justice. The appeal of Hecuba to Ulysses, in behalf of her daughter Polyxena, is however free from this generally pervading fault. Here, the avowed and studied purpose of the captive Queen is persuasion, and the silence of Ulysses, inflexibly calm, gives greater leisure for all the arguments which her passionate anxiety seems naturally to suggest, varied sometimes by indignant reproach, and sometimes by touching supplication.

Soliloquies.

It is obvious that a Poet is in danger of falling into the error in question, in the use of those Soliloquies which are necessary in many cases to instruct the spectator as to the secret feelings and purposes of the speaker. As little use as possible should be made of these, save as meditative preludes or sequels to those displays of Passion which are elicited by the contact of other characters. It may be indeed in some cases consistent with Truth and Nature, that a strongly stifled emotion, like the vindictive exultation of Zanga, should burst out in the first moment of solitude; but the general and proper character of a Soliloquy is repose and reflection; and the acknowledged want of Truth in the mode of its expression suggests the expediency of confining it to that province in which its use is indispensable. We do not mean to apply these remarks to the mixed mode of Soliloquy, or rather Monologue, where the person addresses a conscious or even an unconscious object of the feeling which predominates, as in the eminently pathetic addresses of Medea to her children,

> Ὦ τέκνα, τέκνα, σφῷν μὲν ἔστι, κ. τ. λ.

and of Electra to the urn of Orestes. For here there is a visible object of address, whose reality sustains at once the Passion of the speaker, and the sympathy of the spectator. Though the audience know Orestes to be alive and prosperous, yet the passionate regret of his sister conjures up, as it were, to their eyes the involuntary image of his spirit listening to her words; and unconscious, as the children are, of their situation, an anticipative sympathy in their fate mingles itself with the impression made by their mother's mental sufferings.

In the above remarks, our purpose has been rather to point out deductions which naturally arise from the failures of different writers, than to suggest those rules for the treatment of the several Passions, which tact and experience alone can acquire in a field comprehending the universal nature of Man, and embracing all objects from which he is capable of deriving either pleasure or pain.

Character chiefly compounded of the Passions.

Character, as delineated in Poetry, may be considered in intimate connection with the Passions, since it is, in fact, a combination of two or more of them in different degrees, or which is the same thing, of the habits induced by their constant prevalence, modified by accidental circumstances. It is just as rare to find two Characters exactly corresponding, as to see two faces exactly similar, since the slightest excess or diminution of one of the component parts will, in either case, alter the general bearing and proportion of the whole, and produce a new individual variety. It is certain that in almost every case some master Passion, or habit inveterately indulged, forms, as it were, the basis or ground-colour of a Character, giving to all the remaining parts a quality and tone resembling that of the prevailing tint in a Painting. But as its influence is often latent, or at least less prominent than some other characteristic which takes its source from it, superficial observers are often guilty of the mistake of assuming the latter as the primary source of action; confounding as it were the back-eddy with the course of the main stream which acts upon it, or the apparent motion of the Sun with the real revolution of the Earth which seems stationary. Hence the many seeming inconsistencies of Character which perplex the World in general in the observation of real life, and the blunders often made by writers who venture out of their depth in attempting to embody some new mental combination from their own partial views.

The connection of the Passions with each other as cause and effect, and the laws both of their duration, and mutual reaction, is matter of deep and necessary study for the writer who aspires to any thing like originality in the description of Character. Hence, from time immemorial, second and third-rate Poets have taken refuge in certain hereditary κοινὰ εἴδη, (like the "*père noble*," and other established forms of the French stage,) which remain but little altered by use and transmission, and one sample of which as accurately represents the rest of its class, as Rosencrantz might Guildenstern, or the "brave Gyas" might the "brave Cloanthus." The ordinary description of tyrants, Turks, heroes, rivals, cruel fathers, assassins, lovers, and courtiers, all undoubtedly more or less laudable and indispensable in the conduct of a plot, perform their devoir with the uniformity of well-drilled troops, and it must seriously be owned, with a much more agreeable effect than the half-trained and disproportioned personages, created, as it were, like Frankenstein's monster, from the ill-sorted shreds and patches of humanity, who are sometimes substituted for them by imprudent coveters of originality.

Horace's misconception of Homer.

A striking proof of that difficulty of comprehending the main thread of a Character, to which we have alluded, exists, if we are not mistaken, in Horace's summary of the mental features of Achilles:

> *Impiger, iracundus, inexorabilis, acer,*
> *Jura neget sibi nata, nihil non arroget armis.*

The character described in these lines, which certainly portray somewhat of the hero's outward demeanour, and which from their concise and elegant Latinity, are generally quoted as a perfect abridgement of Homer's conception, might suit equally well with Ferragus or Ascapart, Rodomonte or Ragnar Lodbrog, or any other fierce and strong Barbarian. Now the old Mæonian, with the instinct of master genius, has in his first Book prefixed, as it were, the key of Achilles's character to what he prepares to say of his future conduct:

> Μῆτερ, ἐπεί μ' ἔτεκές γε μινυνθάδιόν περ ἐόντα,
> Τιμήν πέρ μοι ὄφελλεν Ὀλύμπιος ἐγγυαλίξαι
> Ζεὺς ὑψιβρεμέτης.

Conscious that he is foredoomed to an early death, the fiery young Prince is the more morbidly alive to that glory which is to immortalize his span of manhood, and the more jealous of the slightest slur upon his honour. Hence also the melancholy and sensitive cast of mind, which characterises even his ghost, in the interview with

Ulysses in the Shades, and which shows itself in the intensity of his one only friendship. The stain on his honour, accordingly, and the death of Patroclus, produce in different ways a degree of reckless fury, which Horace has mistaken for the habitual character of the hero. But instead of disclaiming Human or Divine laws, we see him, in the Ist Book of the *Iliad*, convening the Chiefs to take measures for appeasing the anger of the Gods, and guaranteeing the safety of Calchas, their interpreter, at his own risk. On every occasion not connected with the sense of his own personal insult, he is eminently just, and strictly courteous; not only receiving the delegated Chiefs with the respectful deference due to heroes grown grey in arms, but even calming the tempest of his first indignation, to welcome the heralds who are come to take away his mistress, with the observance merited by their sacred persons.

> *Χαίρετε κήρυκες, Διὸς ἄγγελοι, ἠδὲ καὶ ἀνδρῶν,*
> *Ἆσσον ἴτ', οὔτι μοι ὔμμες ἐπαίτιοι.*

His wrath is therefore aggravated by the violation of those laws which he respects and practises in his own person.

In the interview with Priam, which may perhaps be said to stand on an eminence of pathos never since equalled, it is evident that the old man has unconsciously touched the master-string in the mind of Achilles, the foreknowledge that he is never to behold that father to whom Priam augurs his return with success and glory. For the first time, the fate of the conquered Hector flashes on him as precisely his own, and the aged King presents himself by anticipation, in the person of the disconsolate Peleus. The hero weeps like a child, and relents in a manner which might appear unnatural to those who do not comprehend the real princely proportions and pith of the Character conceived by Homer.

ure of
il.

We do not scruple to assert that for want of the tact and master-power of conception possessed by Homer, his rival Virgil has failed on the whole in his delineation of the Trojan leader. Undoubtedly many passages of the Character and conduct of Æneas are marked by great power and dignity. As a calm and veteran Leader, the tried comrade of Hector and Sarpedon, he is always himself; and throughout the whole of the IId Book, in which Virgil has filled up the outlines of established fable, he appears as a warrior, a husband, and a father, in the most graceful and natural light. And, in fact, the final tale of Troy therein detailed may be said almost to exceed any thing in Homer, as a piece of vivid and heroic Narrative Poetry. On a view, however, of the whole *Æneid*, the character of the hero appears, as it were, *purpureis assutum pannis;* compounded of remnants of the Royal pall, which do not connect into a consistent garb. The first and most natural conception entertained by Virgil was probably that of a sage and magnanimous Chieftain, disciplined by suffering and experience, and alike master of himself and his purpose; calm, thoughtful, and humane, and schooling a naturally ardent temper by the rules of piety and virtue. Now, in some of the most important crises of his hero's career, Virgil has evidently been misled by the imitative ambition of copying Achilles, a character completely different in age and peculiar circumstances; and accordingly, a mixture of impulse and premeditation seems blended in more than one of his actions, which conveys the idea of a dull, middle-aged actor rehearsing the part of the Homeric Chief. The son of Peleus, boiling with the reaction of a long and inglorious self-restraint from arms, and unconscious of sleep or food since the death of Patroclus, plunges into the battle like a wolf bereaved of its young. He taunts the victims who fall before him, as if unable sufficiently to wreak the bitterness of his first fury, which impels him to commit the indignity on the body of Hector, destined by the latter for his friend. All this would have been horrible and disgusting in cold blood. But the pious Æneas, while fighting with the skill and caution of a veteran, coolly congratulates his dying foes and himself, that they have the honour of falling by his hand. After an interval of some days has composed his grief for Pallas, he murders the disabled Turnus in the act of appealing to his filial piety, diverted from his nearly matured purpose of mercy by an accidental sight. His sense of duty and Religion, which has never suggested a legal reparation to the honour of Dido, appears for the first time when the Gods command him to abandon her; and if any compunctious visitings disturb the calm satisfaction with which he celebrates the Funeral Games in the next Book,

> *Cingens maternâ tempora myrto,*

they seem to remain a secret to the Poet himself. The hero's continence appears to extend merely to useless grief, and his revenge to operate after mature deliberation, amid the full honours of conquest. Thus the Character is only agreeable when viewed in the detached parts unconnected with those of which we speak. That of Achilles, amid all his excesses, is natural, consistent, compunctious, and royal, exhibiting both the Knightly faults and virtues which a Roman critic was incapable of fully understanding.

Manners directly connected with Action and Character.

That which the Ancients denominated "Manners," appears to correspond with what we have enlarged upon under the name of Character; or perhaps may be called the developement of different Characters by contact, drawing forth and exhibiting those Passions which are their component parts, and which influence the event of the story, while they afford an imitative picture of Human life. Sentiments also, of which Aristotle speaks as a separate cause of the actions of men, should seem to be (so far as regards Poetry) the expression by speech or action, of the components of different Characters. Even when these are dissembled, they conform to this rule, inasmuch as they mark the leading feature of the speaker's mind to be falsehood or treachery. Nor can we see that, in reference to any narrative or Dramatic Poem, the actions of men can be separated from their Manners. It is true that the action itself interests the Mind as forming a part in the chain of adventure and vicissitude, which we have already accounted for as forming a separate branch of pleasure to the reader; but the correct description of the Passions which influence the actor, through the medium of those Manners which are their outward sign, is as inseparable from the action, as warmth and motion are from animal life; and with the prevailing tone of these must the particular action be consistently squared, or a link in the chain of illusion is broken. As no idea of Character can be given save by action, or speech, (which is in fact a mode of action,) so does action present no probable or distinct whole to the Mind, excepting as deducible from the Character which originates it.

It would be needless to add that the Manners of any imaginary person should be consistent with the respective age, sex, circumstances, and habits, as well as internally so with each other. The abundant directions of

Aristotle and Horace on this head are merely abstracts of that which experience and observation alone can acquire.

Fortunes of the Hero of a Story.

Medium of character best adapted to Tragedy.

In every Poem of action and narrative, whether Tragic, Comic, Epic, or Romantic, (which may be considered as a minor branch of Epic,) the main thread of interest must consist in the fortunes of some leading person. When these fortunes are the subject of Tragedy, in the special sense in which the term was understood by the Greeks, we recognise the justice of Aristotle's observation, that such Character should be neither eminently virtuous nor vicious. For as the office of Tragedy is to excite Terror and Pity without violating our notions of Moral right, the former emotion cannot be produced without some resemblance between the sufferer and ourselves, nor the latter by the retributive justice which we desire to see realized. The punishment of a monster like Polymestor, however grateful to this sense of justice, excites neither Pity nor Terror for this reason; nor indeed is he represented as more than a secondary personage in the Drama of Hecuba. Again, a Character eminently perfect, when made the subject of calamity, does not come home, in the eyes of the spectators, to that common nature which must be the basis of perfect sympathy, while at the same time the Poet appears wilfully to violate their notions of right, in selecting such a person for the football of fortune. It is therefore more expedient, as well as more consonant with the practice of the best Tragedians, that Characters of this sort should be employed rather as the grand agents in some important crisis of the plot, than as the subjects of the catastrophe. It is consistent with their impassive dignity to cut the Gordian knot, but not to struggle amid its involvements. Thus in the *Œdipus Coloneus*, Theseus cannot be called the hero of the Drama, though his power and justice interpose in a manner which most materially influences its fortunes. "There remains then for the choice of the Poet," observes Aristotle, as the principal character of a Tragedy, a person neither transcendently just and virtuous, nor yet involved in misfortune by deliberate vice or villainy, but rather by some act of human frailty; and this person should also be of high fame and flourishing prosperity." It is obvious that this rule was not adopted in all its branches, even in the subjects of the Ancient Drama. To the fabled Histories of Œdipus, Agamemnon, Ajax, Orestes, Medea, and many others of the like sort, it exactly applies. Not so to those of Iphigenia, Hecuba, Alcestis, or Hippolytus; for in none of these instances are the sufferings of the hero or heroine caused by any fault of their own, and in two of them, the final event is a happy one. But it may be remarked at the same time, that their virtues are of that familiar sort which do not break the link of sympathy between the sufferer and the spectator.

That the hero should be of known and distinguished Character, is a point so evidently essential, that Aristotle has not given his reasons for requiring it. It is plain that in real life the fortunes of great or eminent persons excite more interest and curiosity than those of the unknown, in proportion to their intrinsic claims on attention, and that the large scale on which, by association of ideas, their actions seem to move, is better adapted to "the gorgeous pall of Tragedy," than that of private life; as the spacious dimensions of a Theatrical Scene are more conducive to grandeur of effect than those of a Miniature Painting. They enjoy also a place in our memory already established and recognised; and where their misfortunes are matter of Historical or Legendary fact, the Dramatist may excite a more painful interest at no expense of Poetical justice. The fate of Phocion or De Witt, for instance, if the Characters were imaginary, would exasperate us against the Poet who inflicted it; whereas, known and familiar as the facts already are to us, a Tragedy founded on them would seem a sort of Historical obsequy to the Good and Great, and an appeal to the justice of posterity against their murderers. It may be further remarked also, on this head, that the spirit of the Ancient Drama, like that of the original "Mysteries" of our own Stage, was interwoven with the Religious and Moral habits of the People, and that the instruction which their Tragedians had mainly in view, was more forcibly inculcated by showing that the Hero, King, or Demigod, was equally amenable with the peasant to Divine Justice and the laws of Fate, and equally susceptible of Human calamities.

The modern Dramatists who have most strictly and judiciously adhered to Aristotle's rules for the selection and treatment of Tragic character, are perhaps Alfieri and Schiller, both of whom indeed may be said to move in the trammels of study and discipline with the freedom of master genius. Their personifications of Saul, of Polynices, of Wallenstein, and Mary Stuart, present exactly the medium between Vice and Virtue most conducive to the promotion of sympathy; their names possess the requisite Historic dignity, and the *μετάβασις* or Change of fortune which is the necessary groundwork of Tragedy, is consistent with their actual circumstances.

It does not seem to have been indispensable, as we have already remarked, in ancient Tragedy, that its final catastrophe should be unfortunate, since many well-known subjects both of Terror and Pity existed, in which a happy conclusion was matter of Historic truth, and could not be violated with success. A still greater latitude is prescriptively allowed in the Heroic Drama, which may be considered as the more modern and popular form of Tragedy. But here too it is proved by experience, that the thread of interest can only be maintained by the Historical dignity of the characters, and the magnitude of the plot. Where these are deficient, a meagre, doubting, and unsubstantial effect is produced on the mind of the spectator, who is not prepared by early association in favour of the personages described. The nature of the Domestic Drama, which is a more peculiarly modern offset from the ancient Tragic School, of course excludes the requisites in question. But here (as in the *Fatal Marriage*, the *Gamester*, and the best specimens of the modern German School) the rule of the "Poetics" is for good reasons followed as strictly as is consonant with the nature of the materials. The want of Historical dignity is compensated by the additional depth of the catastrophe, as promotive of Pity and Terror; and the characters of the principal persons, as well as their fortunes, are adapted to display both the *ἀμαρτὶα* and the *μετάβασις* of Aristotle in a prominent view. If indeed his rules for the conduct of Tragedy were not known to some of the writers in question, the instinctive conformity with them which we perceive observed, tends the more to establish the good sense and foresight of the critic.

The above remarks naturally lead us to the subject of Plot, or Fable, the skilful combination of which was considered by Aristotle as the highest triumph of the 'hy the nstruc-on of a ot is the ghest oof of the agedian's wers.

Dramatic Art, inasmuch as, in his own words, "Tragedy is not an imitation of men, but of actions, and a piece defective in every requisite save a proper fable and contexture of incidents, is as superior to fine writing strung together at random, as the outline of a figure is to brilliant colours spread at random." If we may interpret the careless and masterly brevity of the Philosopher according to our own ideas, we conceive the fine writing alluded to, as implying the highest degree of poetical excellence of a merely didactic, descriptive, or expressive sort. It is probable, and indeed warranted by whatever lights we possess on the subject, that no Poem of this description, possessing any claims to superior excellence, existed in the days of Aristotle.

The martial and agitative genius of a community of small independent States struggling against each other for existence, would naturally lead their best Poets to exemplify every thing by action, nor would the patience of their hearers have been proof against disquisitions unenlivened in this manner. In fact, the Odes of Pindar and Tyrtæus, to which, of course, Aristotle could not have alluded in a depreciating spirit, are in a manner pregnant throughout with a spirit of heroic action, although they do not involve any regular story.

To follow up, however, his comparison, we conceive that the knowledge of all the separate materials of Poetry which give life to a plot, is as necessarily implied in the masterly construction of that plot, as the science of correctly drawing the different parts of the body is implied in the faculty of making a correct outline of the whole. It is almost a truism to assert that no artist can compose a whole work, without a thorough knowledge of the component parts. Even the architect, whose materials are furnished to his hand, must study them individually, in order to ascertain their fitness in relation to one another, as well as to the general effect; whereas the Poet has the additional task of supplying every thing from his own invention, as well as of putting it together.

We conceive that the converse of this position, though perhaps not equally obvious, may be almost as safely assumed; that is to say, that the Poet or Dramatist who possesses a discriminating knowledge of the component parts of his plot, will never be at a loss in the arrangement of the whole. A perfect acquaintance with all the master passions of the human mind, in reference to the circumstances which respectively draw them forth, the action and language fitted to express them naturally, their combinations or mutual relations to each other, and their fitness or unfitness for the purposes of Poetry, almost necessarily implies the faculty of combining events in such a manner as may display their operation on an extensive scale.

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In relation to the Fable, or Plot, of Tragedy, the following rules, drawn from the *Poetics* of Aristotle, are sanctioned by the approbation of the best Critics, and the practice of the most successful Dramatists of all succeeding Ages.

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1. The Action represented should be single and entire, on a scale sufficiently large and extended to admit of the *μετάβασις*, *viz.* a change of fortune from happiness to sorrow, or from sorrow to happiness. The incidents which are to produce this change, or revolution, must also be so connected, that if any one of them be taken away, the whole Plot will be destroyed or changed. Nor should any episode, or separate adventure, be introduced, which does not directly bear on the main Plot, and forward its interest.

It may be here remarked, that Shakspeare, whenever he was left to the choice which his own genius suggested, conformed instinctively to these rules, although they hardly could have been revived and recognised in the Dramatic practice of his day. Nothing can be more strictly correct than the connection of events in *Lear*, *Macbeth*, and the other works which may be said to occupy the first class among his Tragedies; and it may therefore be presumed that his more peculiarly Historical Dramas were formed according to some suggested plan, consistent with the temper of the times, in which the Poet was obliged to sacrifice his own better judgment to the desire of popularity.

Discovery.

2. To resume the Aristotelic canon, the Discovery is as important a Dramatic feature as the Revolution, and comes in a manner under the same class with it, consisting as it does in a change from unknown to known, influencing the catastrophe of the Plot. It is not, however, so indispensable as the Revolution, nor, in fact, are either the one or the other absolutely necessary components of a Drama. In the *Œdipus Tyrannus*, for instance, both the Revolution and Discovery come into play, and in perfect union with each other; but in the *Œdipus Coloneus*, the *Hecuba*, and *Troades*, neither one nor the other of these material features are employed in producing the catastrophe, or enhancing the interest. These latter Dramas may be said to meet Aristotle's definition of a simple Fable, as the *Tyrannus* is perhaps the most perfect specimen of the complicated Fable. But as a general rule, the former branch of composition must be pronounced decidedly inferior to the latter, inasmuch as it lacks two of the most important features of Dramatic and agitative interest. It is true that many Dramas constructed on the basis of a simple Fable redeem their defective plan by the union of other circumstances of Poetical merit: but these circumstances are equally effective without relation to their Dramatic nature, and must be very striking indeed to relieve the heaviness of the Plot as a whole. The deficiency or bad management of the Revolution or Discovery, or of both, is that which is generally implied in the familiar phrase that "the Play reads well, but will not act."

Simple and Complicated Fable.

What species of Revolution is best.

The species of Revolution to which Aristotle awards the preference, is a change from good to evil fortune. A happy event, although more generally agreeable to the audience, from their sense of Poetical justice, and their abhorrence of unmerited suffering, he pronounces to be more allied to the nature of Comedy, and less promotive of those emotions of Pity and Terror which should be the leading objects of the pure Tragic style, as distinct from the Heroic Drama. It will be generally found that the judgment of the great Critic is confirmed by the permanent popularity of what are familiarly styled deep Tragedies. For the matter of solid interest involved in these does not so soon wear out by repetition, as the agitative and inquisitive sympathy which, once gratified by a happy event, cannot return again with the same force.

Unities of Time and Place.

The Unities of Time and Place, to which both the Greek Dramatists and those of the classic French School adhered with such rigour, appear now to be in a great measure exploded by the consent of the World, and the dictates of common sense as applied to the laws of Imagination. In recalling the recollection of some peculiar course of events which have formed a passage of connected and absorbing interest in the history of our-

How far these Unities are to be adhered to.

selves or others, or in looking forward to fancied future scenes similarly connected, it is plain that the Human Mind passes with a rapid facility through all the essential links of that interest, abstracting all that is material in the thread of its speculations or reminiscences from the accidents of Time and Place; but preserving that Unity of action which is indispensable in every well-digested story. The laws of Nature will, therefore, be the safest guide to the Dramatist in the arrangement of his Plot with due reference to those established congruities which ought not wantonly to be violated, and which, in fact, will be found, in some degree, to preserve themselves wherever a strong and uninterrupted interest is kept up, and a perfect illusion created. A chain of circumstances can hardly dwell on the recollection as a combined whole, without implying so much of limitation as to Time and Place, as may correspond with the Unity of Action. And, at all events, the interposition of a week, or a month, between one Act of the Drama and another, and the corresponding change of scene, is not a greater fraud on the Imagination, than the necessary presence of the audience, before whom the most private and confidential conversations of the actors take place.

How far Epic Poetry is subject to the rules of Tragic Plot.

From the obvious difference between narrative and personification, Epic Poetry has always claimed a more extensive latitude than the Drama in the respects alluded to, a latitude, indeed, answering to its wider range of events. The Unities of Time and Place cannot in this instance be strictly enforced under any pretence; but the Unity of Action, founded as it is on a natural and not an artificial principle, can be as little dispensed with as in the Drama. An Epic Poem is neither the history of one man's life, nor of the unconnected actions of many men within a limited space of time, but a narrative of circumstances combining towards one and one only main result; so that even those parts which are denominated episodes, may contribute to such result in the manner of contrast, embellishment, or furthering cause. The fall of Man, the triumph of Achilles, the rewards of the respective wanderings and dangers of the Chiefs of Ithaca and Troy, thus form severally the leading features of the four standard Epics which stand on an exclusive eminence. Nor does any episode occur in these, which does not strictly conspire to the main event of the story.

The Revolution and Discovery are features as material in the Epic as in the Tragic style, although not absolutely indispensable, and their management is the same in both cases. The emotions of Terror and Pity, which are the great bases of Tragic interest, are also most essential features of the Epic Poem, although combined with others equally important.

Comedy considered in reference to these rules.

In the construction of the Comic Drama, the same rules as to the mere management of Plot apply, as in Tragedy, although the end sought is wholly different, consisting not in the excitement of Terror or Pity, but in a familiar and ludicrous imitation of human manners. It is necessary that a certain Unity of Action should always exist in a Comedy, as implied in the nature of a regular Plot; although it is not so indispensable as in Tragedy. In the latter case, the subordinate occurrences and characters are chiefly interesting as they tend to the developement of that final catastrophe on which the mind is intent, and influence the fortunes of the principal personage: in the former, these are in themselves a principal source of pleasure to the audience, and the interest taken in the final event is comparatively weak. The same difference exists as between a race in which every faculty is wound up to the rapid attainment of the goal, and a leisurely walk undertaken with an equally definite purpose, but diversified with occasional digressions, to catch butterflies, or jest with passers by. Hence, in Comedy, the attention is more equally divided among the different characters with whom the foreground is, as it were, filled, all contributing their share of the amusement which is elicited by contact with familiar life; as in the Dramas of Moliere, Farquhar, and Sheridan, as well as in the *Merry Wives of Windsor*.

The Unities of Time and Place, although as easily to be dispensed with in Comedy as in Tragedy, are perhaps more readily preserved in the former, because the events thereof are on a smaller and more domestic scale, and if not taking place within the supposed limits of a private house, at least extend not beyond those of a confined circle of acquaintance. The effects of the Revolution and the Discovery, if indeed it be allowable to use these grave Tragic terms in reference to more familiar subjects, are equally striking here as in the more serious Drama. The *School for Scandal* and the *Rivals*, abounding as they do in wit, humour, and character, still derive much additional interest and amusement from the judicious management of these principal hinges of the Plot.

Comedy in a general view.

The real Hero of pure Comedy, as of pure Tragedy, is properly the person* on whose head the catastrophe is made to fall, consisting generally in some calamity of a ludicrous rather than of a destructive nature, and perfectly in union with the spectator's wishes and sense of Poetical justice. It is true that as a concession to established custom, and a means of maintaining the thread of the story, a couple of lovers are necessarily introduced in most Comedies, whose final union is the ostensible business of the catastrophe. It seldom, however, happens that these personages possess the same spirit and character as Lydia and Absolute in the play of the *Rivals*; and the male in particular is generally doomed to the rank of an indispensable biped, such as Fenton, Frankly, or Heartfree, the *rois fainéans*, as it were, of the scenes in which Falstaff, Ranger, and Sir John Brute figure as the master spirits. It may here be remarked, in reference to the last-named character, that wide as may be the latitude of a branch of Literature devoted to familiar life, Comedy has a certain degree of decent dignity to keep up, and although not professing the sustained tone of Tragedy, is equally bound not to encroach on the limits of the *μιαρὸν*, (the disgustingly mean and sordid.) In this respect, Shakspeare has shown a good taste little to be expected from the rude Age in which he lived. It is not our purpose to add any thing in the way of dissertation to the volumes which have been written on his unique conception of the portly Knight of East Cheap. Suffice it to say, in relation to our present point, that Falstaff, with all his real grossness and knavery, is rendered by the art of the Poet as superior to the bestial herd which wallow in the Augean stalls of Vanbrugh, Wycherly, and Etherege, as "Hyperion to a Satyr." So imbued is he with the spirit of buoyant and kindly drollery, that his worst actions seem as it were performed rather for the joke's sake, and in due discharge of the semi-historic part which he fills in reference to Prince Hal, than from roguish or vicious motives: nor

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* As, for instance, Monsieur Jourdain, or the luckless De Pourceaugnac.

does his example appear more practically dangerous than that of Harlequin or Polichinelle, those never-dying functionaries of the minor stage of Comedy. Still less has Shakspeare violated the rules of propriety in the general class of his ludicrous characters. There is nothing coarse or revolting either in the harmless absurdities of Sir Hugh Evans and Sir Andrew Ague-Cheek, or in the more latent foibles of the grave Malvolio; no personage, in short, of this class is introduced for the spectator's amusement, whom he resents to behold "eating a posset this night at Page's house," or joining in any other manner in the festivities accompanying the conclusion of the Drama. Whereas the consummation devoutly to be wished in those Comedies of later date, which may be said to compose the anti-fanatical School, is that the whole Dramatis Personæ may be sent as ribalds and strumpets to the House of Correction, under the jurisdiction of the abused Alderman Fondlewife, or some such disciple of Barebones and Hugh Peters.

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We have made no allusion to the Comedies of Aristophanes, both because the genius and writings of this extraordinary man have undergone the exclusive examination of abler criticism, and because the discussion belongs more to the History of the times than that of the regular Drama. Instead of the author, dependent on the approbation of his audience, and coming forward in every fresh instance with the modest anxiety,

Populo ut placerent, quas fecisset fabulas,

Aristophanes appears to have been the licensed *Terræ Filius*, and Dictator in the Province of National and Political Satire, among a People as wayward, gifted, and whimsical as his own Muse. The private history of all Ages shows that tyrants have cheerfully tolerated from their jesters those biting gibes which they would have punished with death if uttered by a Minister or Councillor; and on this footing Aristophanes seems to have stood with the most capricious and savage of all tyrants, the Δῆμος; a footing more gratifying to his self-esteem as an influential member of the Commonwealth, than could have been the success of any effort in the more regular Dramatic line, of which a few elegant specimens remain in the fragments of Menander. In fact, the *Birds*, the *Wasps*, and most of the other daring extravaganzas of the same pen, differ as widely in essence and purpose from the *bene morata fabula*, which the Ancients considered as the province of Comedy, as the Life of Pantagruel does from a Romance, or Knickerbocker's History of New York from a real narrative.

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In remarking on the subject of Comedy, we have been induced to draw our instances rather from the Modern than the Ancient School of Dramatic Art, inasmuch as the former, if not indeed decidedly the superior of the two in every respect, is at least better adapted to exemplify those conceptions of the ludicrous which are familiar with the reader's associations, and to present a happy medium between the different styles of Plautus and Terence. The pure Latinity and the well-bred tone of the latter, as well as the arrangement of his Plots, entitle him to a degree of merit which would be more duly ascertained were we in possession of the Works of his supposed original, Menander; and his delicacy and propriety as a familiar Heathen Moralist cannot be too highly praised. But when contrasted either with Aristophanes or Sheridan, or Shakspeare when in a merry mood, the Roman Dramatist must be utterly acquitted of the fact of ever having promoted that laughter which our modern ideas of Comedy require as an additional relish to the pleasure derived from instruction and good taste. His scenes remind us of a table laid with the utmost neatness in a saloon of elegant proportions, but presenting an abstemious banquet of white bread and spring-water, affording little temptation to more than a moderate indulgence, although pure and good of their kind.

We need hardly advert to the anomalous performances, many of them not deficient in talent, attraction, and occasional humour, which the French have whimsically characterised by the term of *Comèdie Larmoyante*, and which at one time almost monopolized the English Stage. To submit these to the rules of regular criticism, would be departing too widely from the proper subject of Poetry, which nevertheless, in reference to the Comic Art, we have considered as connected with a branch of works not couched in metrical language. Those Comedies indeed in which this more classical form has been adopted, may still be considered as less depending on the peculiar aids of Poetry, than any other species of verse; as the point of a jest or familiar allusion is lost by amplification or figurative language, and the illusion of imaginary dialogue in this case disappears, unless kept up in words and forms of speech closely resembling those of real life. Nay even in the most successful branch of Comic Poetry,* as embodied in narrative or reflection, and therefore not necessarily restricted to the same limits as dialogue, additional humour and quaintness is given by a close imitation of colloquial idioms, with no further alteration than the metrical arrangement of words.

Comparison of Imitative with Non-imitative Poetry.

In treating of so boundless a subject as the Art of Poetry in general, we have been compelled to restrict ourselves to those more regular and defined branches of it, which may properly be named imitative, and which are distinguished by a narrative or Dramatic Plot. The essential matter which gives to Poetry its dignity, spirit, and interest, the different sources of which we have elsewhere attempted to define, is precisely the same in those more numerous departments which may be styled generally, the Descriptive, Expressive, and Didactic; and although concentrated more effectively to a point by a judiciously arranged Plot, the expected catastrophe of which may keep curiosity awake, it does not necessarily abate any portion of its quality when independent of such Plot. The *Georgics*, as well as the more modern Poems of the *Seasons*, the *Temple of Fame*, and *Childe Harold*, abound with every Poetical excellence which can exist apart from incident and character. Dryden's well-known Ode on *Alexander's Feast*, and his *Absalom and Achitophel*, evince, by their different styles of merit, a power still more extensive, and evidently equal to the highest flights of Epic song, had the Poet's leisure and circumstances admitted of its cultivation. These latter, indeed, may be classed as specimens of Imitative Poetry, although the one or two circumstances which form their groundwork hardly deserve the name of incidents.

Having touched on the characteristics of some of the principal branches of Poetry in reference to the Passions with which they are chiefly connected, we shall not discuss them more particularly. On the subject, however, of Sacred Poesy, the most dignified and important of all, a few remarks may not be misplaced, with a view to account if possible for the reasons why it has not re-

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* As for instance, *Beppo*, and the Works of Wolcott and Colman.

ceived an improvement commensurate with that bestowed upon other metrical works of genius.

Causes of the neglect of Devotional Poetry.

We shall perhaps be anticipated in the obvious remark, that the expression of Christian devotion can be no other than revolting to the taste of the irreligious and profligate, and dull to that of the mere decent moralist. To enumerate the proportion which such persons bear to the number whose habits enable them to relish meditative and devotional subjects, would be a task at once painful and thankless in an Essay of the present description. But this is not all. The peculiar doctrines of Christianity, grounded as they are on the sound basis of the Reason and the Affections, still contain many points too mysterious to be made clear to the *Imagination*, and unparalleled by any thing with which that faculty is usually conversant. That which is reserved by God to baffle the pride of Metaphysical speculation, is little likely to be seen plainly by an intuitive process of the Mind. Again, a peculiar class of Christians, whose motives cannot but be respected, and whose powers must in some instances be acknowledged by all serious minds, have adopted a tone of thought and phraseology on sacred subjects, too much coloured by the influence of ill health or despondency.* We speak not of the nauseous familiarity or the exclusive arrogance of sectarian Hymns, as any stigma on those to whose minds they may convey sincere and pious impressions: but rather of one or two instances where men of a high imaginative cast of thought have rather chosen to dwell on the awful denunciations of Scripture, and to bewilder themselves with speculations on the unrevealed joys of Heaven, than to illustrate the practical beauty of a Religion "whose ways are pleasantness, and her paths peace." Milton, a stern and Religious Republican rather than an enthusiast, is as little chargeable with such bad judgment, as with the principles of the Fifth-Monarchy-men. But the same gloomy fanaticism, whose disgusting profanations were formerly acted in our high places, while its fiat forbad the peasant from those innocent and cheerful commemorations of sacred seasons for which a precedent may be found in the Passover, has not confined its mischief to the fatal reaction of morals by which the times of Charles II. were distinguished. Still subsisting as it does, although in a form more sincere and respectable, it has tainted, by a similar reaction, the sources of that wholesome and exalted pleasure which the imagination should naturally derive from Religious subjects, when not warped by vicious habits; and has imposed the bar of false shame upon the social confidence of Christian men in reference to the most important object of their "business and bosoms." If considered with the eye of Truth and Reason, as proceeding from the Author of all good gifts and affections, the true Christian spirit far exceeds the visions which fabulous Writers have formed of the Golden Age.

Real view of the subject.

It is the sound and comprehensive basis of all that is cordial, courteous, and generous in domestic and social life, of plain and honest dignity of character in the peasant, of honour and integrity in the man of active business, and of true courage, candour, patience, and disinterestedness in the Statesman or Patriot;* of all the noble qualities, in short, with which it pleased the Creator to endow, by some special light of Nature, such men as Phocion, Aristides, or Germanicus.

It would be better judged, therefore, if men of Imagination would attempt to familiarize the mind with Religion under such wholesome and exalted views as these, rather than encroach, by their minatory clauses, on the severe responsibilities of the Divine. If the intention of Poetry be to give pleasure without violating Truth, and to draw that pleasure from familiar sources of Fancy, its province does not extend necessarily to every thing consistent with that Truth. The Poet who makes the intenseness and eternity of hell-torments his favourite theme from a mistaken sense of duty, might equally plead the excuse of Truth in describing the agonizing details of a surgical operation; ignorant that there are many things instinctively shunned by men, which are not therefore the more fitting subjects for Poetry.†

One of the best models of devotional verse may be found in the well-known volume of the *Christian Year*. The author, a Divine of sound piety and original taste, has perhaps approached as nearly to the limits of mysticism as is consistent with good judgment, and too near to please volatile readers. Seldom, however, is any train of thought introduced, which is not familiar to the associations of serious minds; and most are finely illustrated by some familiar image drawn from the beauties of Nature, the charities of domestic life, or the sacred occurrences of the Gospel History. This familiarity, however, does not extend beyond the bounds of sound judgment and Religious propriety. The reader is as it were invited to share in a sacrifice culled from the choice productions of the visible World, and placed at the feet of the altar; not to lift presumptuously the veil which conceals the Holy of Holies.

Psalmody.

It is evident that Psalmody, from its very nature, ought to rest on a still broader and more common basis. As a species of sacred composition professedly intended to be "said or sung" by large congregations,‡ it should be couched in that simple and grand form, which may meet the most obtuse capacity, and the lowest degree of Religious advancement. The one and only model to be adhered to in this department, is bequeathed to us in those Odes of the Sacred Psalmist evidently intended for

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* We particularly allude to Pollok's *Course of Time*; a Work whose dignity and force of Fancy constitute it a leading feature in modern Literature. Its faults, the most offensive of which is the uncalled-for attack on the British Hierarchy, may find palliation in the youth, the zeal, and the peculiar circumstances of the author, now unfortunately no more. He seems to have imbibed too strongly the austere spirit of the Scottish Covenanters.

* *Soumis avec respect à sa volonté sainte,*
Je crains Dieu, cher Abner, et je n'ai point d'autre crainte.
Athalie.

† See our previous remarks on τὸ μιαρὸν, p. 661, as extended to subjects capable of neither hope nor alleviation.

‡ It is lamentable to think that so effective and essential a part of the Church Service should have fallen into such general disuse. At present, it is either an exclusive mystery practised by conceited knots of village worthies, or an office contemptuously delegated to yelling charity-children. The Dissenters are wiser in their generation as to the duty of "praising God with the best member they have," and "singing praises lustily with a good courage;" texts on which it might not be inexpedient for our own orthodox Ministers to expatiate largely and specially to their congregations. The opinion expressed in Burney's *History of Music*, that the sound of many voices, however rough and ill-tuned, cannot create a general effect of discord, has never been a paradox to any person of a really musical ear, and furnishes in part an answer to the practical difficulties urged on this subject in support of indolence and false shame. We understand that the present Bishop of Down and Connor, a Prelate well known in early life for his Poetical talent, and zealous for the promotion of Psalmody, has given to the World specimens in this style of translation. But as yet no authorized selection (which ought fairly to include certain parts of Sternhold, and even Tate) has superseded the present versions.

the public service of the Temple. Composed as these were by one who united the chosen gift of inspiration with the character of Monarch, Warrior, and Sage, they breathe as it were the united voice of a mighty multitude like the company of Saints and Elders in the Revelations, even through the inadequate medium of prose translation; and they present an inexhaustible fund of sublime and solid matter, which, although transcending all imitation, might amply reward the efforts of the most Poetical translators. Unfortunately the only authorized metrical versions of the Psalms exist in a shape calculated to scandalize all hearers of moderate taste and education.

The faults of Sternhold, much as it has been the practice to depreciate his translation, may be in some degree palliated by the obsolete nature of his diction; and in fact hardly extend further than the extreme of a rough and yeomanlike simplicity, which for the sake of our forefathers we may be inclined to tolerate with indulgence. In several instances, particularly the 100th Psalm, Sternhold can hardly be improved upon as the sober lyrist of a country church. In the 18th Psalm he rises, by a strange sort of intuition, into a strain of sublimity worthy his original. In no case, however, does he convey any train of association so inconsistent with his subject as the tripping pastoral strain[*] intended by Merrick as a paraphrase of "The Lord is my Shepherd;" or as the nauseous whinings of Tate and Brady, which still continue a by-word and a jest on our admirable Church service.[†]

The immeasurable superiority of David's Psalms, as might be expected, shows in a disadvantageous light of contrast any thing which the invention of Man has devised as a substitute for them in their peculiar department. Hence the greater part of what are styled Hymns, although commendable as the expression of devout feeling, appear tainted, in comparison, with a littleness of conception, and a fulsome familiarity, adapted rather to the worship of sectarian tabernacles. Dryden's translation of *Veni Creator Spiritus*, and the noble conventual strain of *Dies Iræ*, are indeed happy exceptions. It may be remarked also, that the one or two Hymns adapted by our Liturgy to particular Festivals, if not possessing any Poetical merit, are couched at least in a tone of devout simplicity which cannot offend the nicest judgment. The Christmas Hymn, "While shepherds watch'd their flocks by night," is perfect in its way as a mere metrical arrangement of the narrative of Scripture, and better adapted to commemorate an event so transcendent, than any of those little ambitious attempts at Poetry, which are often substituted. To those who have heard it sung on the night of Christmas Eve by the rudest village choir, according to a good old custom[‡] somewhat fallen into disuse, the effect is very striking and peculiar. The plaintive and flowing tune to which the words are adapted, the hour, the occasion, and the condition of life of the singers, produce an illusion perfectly in character with the associations then presenting themselves to the most unimaginative Christian mind.

Imitative Sacred Poetry.

In the Epic and Dramatic style of Sacred Poetry, there are few instances of success. The events of the New Testament are of so exclusively hallowed a nature, as to impose a restraint on the Imagination of well-regulated minds; a restraint which, perhaps, may have contributed to the failure of Milton in his *Paradise Regained*. Those, however, connected with the History of the Jewish Theocracy do not present the same difficulty, and considered in a merely human point of view, exhibit an extraordinary series of incidents and characters abounding in all the higher ingredients of Poetry. Those circumstances, nevertheless, which are in themselves the strongest living testimony to Scriptural Truth, have, by a natural effect of association, contributed to debase these ingredients in the eyes of those whose imagination outruns their judgment. Accustomed from their infancy to associate the name of Jew with habits of sordid traffic, and the peculiarity of countenance, which possibly may be a modern feature of the Divine dispensation for obvious purposes, the undiscriminating are apt to confound the Patriots and Heroes of Holy Writ with their obscure descendants. Yet even when abstracted from all idea of the sacred cause which dignified their exploits, the names of Judas and of Eleazar may at least parallel those of Decius or of Wallace,[*] and the lamentation of a brother in arms over the faithful and princely Jonathan, may challenge a competition with any eulogy of Bard over true Knight. Nor do we conceive (speaking rather in simple truth than in levity) that any fabulous legend of the Round Table can exceed the true tale of David's three "mighty men of valour," breaking in their loyalty through an armed host to bring their Sovereign a draught of water; or that David's noble refusal to drink the price of his subject's blood,[†] may not match the memorable episode of the British Knight and

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[*] Lo! my Shepherd's hand divine!
Want shall never more be mine.

And again, in his pillage from Addison:

To the streams, *that soft and slow*
Through the *verdant landscape* flow.

[†] The 121st Psalm, and one or two others, certainly constitute exceptions to the general context of the ill-fated Laureate and his assistant. The merit, however, in these cases, consists in having adopted the plain old English style of Sternhold.

[‡] *Heu pietas! heu prisca fides!*

Though we neither affect to deprecate modern refinement, nor consider our ancestors of the last century as better or wiser than the present generation, it is impossible not to regret the decline of that cheerful and genial *petite morale* of the Church of England, which prevailed in the days of Addison; expressed by the Yule-clog, the Christmas Carol, the Baron of beef which feasted the poor in the Lord of the Manor's kitchen, and that worthy personage himself, marshalling his family and guests in their best attire into the well-hollied pew; customs at which the modern fanatic would frown, and the infidel sneer.

Hâc instat lupus, hic canis urget.

[*] "Eleazar also, surnamed Savaran, perceiving that one of the beasts, armed with royal harness, was higher than all the rest, and supposing that the king was upon him, put himself in jeopardy, to the end that he might deliver his people, and get him a perpetual name. Wherefore he ran upon him courageously through the midst of the battle, slaying to the right hand and the left, so that they were divided from him on both sides. Which done, he crept under the elephant, and thrust him under, and slew him, whereupon the elephant fell down upon him, and there he died." *Maccabees*, book i. ch. vi.

[†] If the one fatal crime of David be put out of the question, his character is distinguished by those frank and magnanimous features, which are considered the marks of the true King, when exemplified in such men as Francis I. or Henry IV. of France. His dignity is rather increased than lowered, when we read of his dancing before the Ark of the Lord at the head of his People, a condescension not understood in its proper sense by the proud daughter of Saul. There is something in this trait truly manly and royal, as a triumph over false pride, and in keeping with the feast given by him to the whole nation, when the ceremony was concluded. As a public act of homage joyfully performed by the Father of his People, its effect must have been incalculable on the minds of the Israelites.

the Wounded Soldier. Yet it cannot be disguised, that such heroic annals as these, as well as the records of the wisdom and magnificence of the Monarch whose name is even now as a magic spell to Oriental nations, and the combination of sublime words and circumstances attendant on his consecration of the Temple, are often recollected as nothing more than the dull task of childhood,—the actions of a stiffnecked people marked by the finger of Divine reprobation.

It is possible that the mistaken associations to which we allude, may have been strengthened by the unclassical terminations of Hebrew names, and the affected use of them by the Puritans in their baptisms. And even to minds superior to such trivial circumstances, the most memorable actions in Holy Writ may present themselves as the special effects of an overruling Providence, rather than as implying any individual power or character in the performers: a point on which it is difficult, as in the instance of David's heroic encounter with the Giant of Gath, to draw the line between primary and secondary causes. To others also, fully alive to the dignity and beauty of the Sacred Writings, it may have seemed inexpedient to allow their imaginations to wander on subjects connected more or less with points of Faith. Be this as it may, the fact unwillingly presents itself, that the Scriptures have in most instances remained a sealed book to the Poet in search of materials for his Art.

We need not quote the Works of Milton, the *Saul* of Alfieri, and the *Athalie* of Racine, as proofs how these difficulties, if they indeed exist, may be surmounted by powerful minds. The Drama of *Samson Agonistes*, in particular, although departing in no point from the minuteness of sacred tradition, conveys the idea of a colossal image carved from a rock in the true style of classical grandeur and repose. Nor does the accustomed vigour of Lord Byron appear to desert him in his *Hebrew Melodies*, the solitary tribute of his genius to sacred subjects.

We have been tempted rather to exceed our usual limits in the discussion of the dignity and capabilities of Biblical themes for Poetry, considering the general exercise of the Art as at all times an important link of sympathy and communication among civilized nations, peculiarly adapted to commemorate those feelings and recollections which they possess in common. The greatest triumph of the Muse of Euripides was to find that the recitation of his verses had softened the minds of national enemies towards captives of the same blood and language. Thus those men of genius in all Christian Countries who know how to unite the wisdom of the serpent with the harmlessness of the dove in their treatment of sacred subjects, eschewing at once sectarian rancour, doctrinal discussion, and ill-judged familiarity, may become most powerful coadjutors to the professed Divine and Moralist, in drawing closer those bonds of union among the worshippers of the true God, which constitute the true essence of humanity and the law of nations. Those whose differences of creed forbid their meeting in a common place of worship, may recognise in the Poetry of Milton or Klopstock, the cementing principles of a Religion first proclaimed by the memorable words, "Glory to God in the highest; on Earth peace; good will towards men."

Having hitherto confined ourselves to the discussion of the subject-matter of Poetry, it remains for us to speak of the causes calculated to give it a due effect; of whatever, in short, is comprehended under the terms of diction, arrangement, ornament, and taste.

Selection of Poetical circumstances.

The judicious selection of those circumstances in the treatment of any given subject, which shall illustrate it in the most Poetical and striking manner, is one of those points where rule ends and genius begins; as well with reference to the actions and words of imaginary characters, as to the positions of still or animated Nature, under which they take place, serving as it were the purpose of a background in harmony with the leading features of the picture. Thus the time of day, and the cheerful sunshine, conspire to give a more striking interest to the fate of Ugo, in the execution scene which terminates *Parisina;* quitting as he does the bright scenes of Nature in the prime of youth and strength. Thus also in the noble lyric known by the homely name of *Hosier's Ghost*, the appeal of the departed Spirits is rendered more touching by introducing them as hovering over the scene where their lives were ingloriously cast away. It may be remarked also, that writers of an inferior grade, when tasked beyond the powers of their genius by some appalling conjuncture of their Plot, fly to the ready melo-dramatic resource of a thunderstorm, a meteor, or an earthquake; as an indifferent musician will sometimes wind up his performance with an accompaniment *con strepito*.

Clearness of Conception.

To resume our subject, the ἐνάργεια, or clearness of conception, on which the Ancients laid such stress, can never be kept too strongly in view. As the mind of the reader cannot take in above a certain quantity of ideas without fatigue and confusion, it is the object of a masterly Poet to select one or two circumstances, which imply or represent a variety of others, equally probable and connected with the subject, but not equally vivid or forcible. Thus Shakspeare has by a few words presented the most perfect picture of kingly bearing and masculine beauty, where an inferior Poet would have wasted as many verses in describing the shape of the monarch's features, the mould of his limbs, and the colour of his hair and eyes:

> Hyperion's curls, the front of Jove himself,
> An eye like Mars, to threaten and command,
> A station like the herald Mercury,
> New-lighted on a heaven-kissing hill.

It is in fact the concentrated abundance of a fine Imagination that thus vents itself in "thoughts that breathe, and words that burn."* Familiar as a Poet of real genius must be with a cloud of images and circumstances illustrative of the subject of his contemplation, he is able to view it at once in all its bearings, as an architect studies the general effect of an edifice, or as a commander draughts his best disciplined troops to a chosen point of action; and to select those leading features which harmonize at the first glance into a graceful whole. By a parity of reasoning, the laborious

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* Dante has with a single stroke of his pen, in the line

In guisa di leon quando si posa,

conveyed the most perfect image of the mien, the countenance, and almost of the previous history, of an indignant spirit, in which pride and suffering had worn themselves to melancholy apathy. This is a true exemplification of "the Poet's eye," as the following passage is of the true Poetical feeling briefly expressed:

> He sleeps not where his fathers sleep;
> But who hath a grave more proud?
> For the Syrian wilds his record keep,
> And a banner is his shroud.

minuteness with which some writers multiply trivial circumstances, may be judged to arise from an habitual poverty of conception, and a consciousness of deficiency which renders them anxious to say every thing which can be said, in the hope that something at least may strike their hearers. To preserve our analogy, they appear in the situation of an unskilful General, embarrassed by the conduct of new-raised levies, and hoping that numbers may balance want of discipline. By dint of painful thought, many ideas occur to them perhaps for the first time, not mellowed down by previous familiarity to that state in which their spirit and flavour can be extracted. In contrast with writers of the intuitive grasp of mind to which we have alluded, they resemble, as it were, the stationary dwellers on a mountain, who can describe accurately every dingle and crevice on its face, without ever having taken a full view of its height and proportions.

Ovid, whose greatest merit lies perhaps in the liveliness and accuracy of his descriptions, is nevertheless a writer of this petty microscopic class. He seems to have been peculiarly ignorant of the difference between expressing a whole and a number of parts, and of the power of concentration which is even indicated by the analogy of Nature. A clap of thunder divided into a hundred paltry reports, or a cataract drawn off into a hundred small streams, loses both its effect and its nature; and in the same manner is the momentum of a circumstance, in itself striking, weakened on the mind of the reader by minuteness and verbosity. Thus the transformation of Niobe loses much of its force in the *Metamorphoses*, from the repetition of a number of circumstances of a nature similar to each other:

Ipsa quoque interius cum duro lingua palato
Congelat; et venæ desistunt posse moveri;
Nec flecti cervix, nec brachia reddere gestus,
Nec pes ire potest.

It should ever be recollected, (a fact of which Ovid and similar writers appear little aware.) that the Imagination of all readers capable in any degree of relishing the beauties of Poetry, is in active exercise during its perusal, and is as jealous of the performance of its own office without superfluous aid, as the mouth is of the privilege of masticating its own food. The sense of satisfaction in learning and inferring somewhat, which is considered by Aristotle as a distinct pleasure in itself, is disappointed by the officious suggestion of those ideas which a Poet of genius and judgment leaves unexpressed, well knowing that he has touched the one master-string to which they all correspond. More peculiarly, when the mind of the reader is hurrying on to any crisis of eventful interest, is it necessary to keep pace with the rapidity of his thoughts, instead of pausing on minute particulars.

It must be confessed, that in these cases "the good Homer" not unfrequently betrays that "occasional drowsiness" which ancient Critics have attributed to him. The fault may be the more venial, when considered as the effect of the genius of an Age when the success of battles depended rather on individual strength and dexterity, than on combined manœuvres, and when most of his audience, from a natural fellow-feeling, hung in the same suspense on the event of every thrust and parry of his imaginary champions, as on the final catastrophe of a tale. Hence his battles become in many instances a tedious detail of single combats, during which, as on a Dramatic Stage, the whole din of war appears to the Imagination to "suffer a syncope and pause" contrary to Truth and Nature.

It may be doubted, indeed, whether a merely general picture of the battles with which the greater part of the *Iliad* is necessarily filled, would have been sufficient to form a body of matter without the introduction of the details of particular deeds; and possibly too these very details may have been intentionally spun out by the Poet, to form as it were a laborious contrast of the toil and tug of war preceding the reappearance of his Hero, to the decisive rapidity with which Achilles, when once in arms, overthrows every obstacle, striking terror by his very look. At all events it is plain that Homer, whenever he pleases, is as thorough a master of the art of blending his masses of action with fine general effect, as of every other power constituting the true Poet. The muster of the Myrmidons, "rushing to the battle like thirsty wolves to a spring," and the defence of the ramparts by Polypœtes and Leonteus, animated by a rapid succession of the most powerful similies, may be mentioned among a hundred other instances of this spirit stirring faculty.

Examples.

As it can hardly be considered beneath the dignity of our subject to instance that which has been praised both by Addison and Sir Philip Sidney, we would allude to the ancient Ballad[*] of *Chevy Chase*, as eminent, among its other merits, for its uninterrupted flow of martial action, and the admirable *keeping* which it preserves between the individual deeds of the leaders and the mêlée of their bands. The excitement of the whole moving scene never seems to flag for a moment; the words of the Chieftains are as brief and ardent as the sparks of fire struck from their weapons, and are uttered with the decisive quickness of real action; and each exploit in succession assumes a momentary prominency amid the general mass, like the occasional blast of a trumpet, enhanced in its effect by the accompanying din of battle which it overpowers. The bard never pauses in his full career, till the conclusion of the contest reminds him to sum up the mutual losses, and pay the tribute of honour to the fallen. Thus the contrast is rendered more striking, when the battle seems to cease for a moment on the deaths of the respective leaders, in a manner critically well-judged. The reader is placed exactly in the probable position of the combatants, sorrowfully arrested for an instant by the spectacle of two noble Knights dying with sentiments of honour in their mouths. His

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[*] The term of "Ballad" is very indefinite in its general acceptation, including classes of composition wholly different in themselves, of which the only common characteristics are brevity of metre, and simplicity and perspicuity of language. *Hosier's Ghost*, to which we have already alluded, is, in fact, a Lyric Ode of great beauty, and produced in its day a singular political effect. *Chevy Chase*, the *Battle of Sempach*, and the more finished productions of Sir Walter Scott's school, may be styled Heroic Legends, in common with *Marmion*, or the *Lay*. Wolfe's *Tribute to Sir John Moore* (eminent for feeling and for vivid imagery) is of the nature of a warlike requiem. As specimens of the Ballad proper, adapted practically for the voice, the *Irish Melodies* are preeminent, wherever the author abstains from seditious allusions, and from those laborious refinements which the simplicity of song rejects. One indispensable requisite in the real Ballad is, that the thoughts should convey themselves clearly to the mind before the corresponding bar of the music has passed from the ear. On the whole, we know nothing in this peculiar class of composition superior to the simple strain of O'Keeffe:

Oh the moment was sad when my love and I parted,
Ma vourneen delish Eileen oge, &c.

attention is then fixed on the deliberate purpose of the English archer to avenge the death of Percy, and he finds no tediousness in the description of the tough yew, the cloth-yard arrow, the strong pull, and the deadly aim, which are to overtake the retreating foe: on whom however, when once fallen, the Poet, with excellent judgment, wastes no more words in expressing how he gnashed his teeth, bit the dust, and the like commonplaces, but instantly resumes the general thread of his subject.

The VIth Canto of *Marmion* is a distinguished instance of a similar good taste, founded on Truth and correct analogy. For the very position which would convey to a real spectator the most absorbing impression of interest in the fortunes of a hard-fought field like that of Flodden, would be precisely that in which the Poet has placed Clara and Fitz-Eustace; far enough removed from the battle to command a leading view of all its fluctuations, and sufficiently near to mark the particular exploits and dangers of their own band. Thus, fixing the reader's point of sight according to the most accurate laws of Poetical perspective, he presents a general glance at the contest, boundless as the ocean in a storm, yet diversified and grouped by the leading features of the banners, the crests, and the war cries, which respectively mark the points in which the most daring knights are engaged, and the fight is most obstinate. An inferior Poet would have plunged the reader into the midst of the mêlée, to have shown his own Homeric accuracy in describing individual thrusts and wounds; thereby anticipating his Imagination in unnecessary particulars,[*] and leaving it unfilled by any grand general idea. But in this, as in many other similar instances occurring in his Prose Works, of a nature to be judged according to the rules of Poetry, Sir Walter Scott has judiciously followed the precepts of Burke and Bacon, "that infinity is a principal source of the sublime,"—and "that the office of Poetry is to accommodate the shews of things to the desires of the mind." According to the primary law of sympathy, the reader places himself in the situation of the imaginary spectators, made more anxious by the degree of personal risk which they incur; and brooking no trivial interruption from the main objects of interest, his fancy is awake to the slightest circumstance showing how the tide of battle flows round the important land-marks on which his eye is fixed; the royal standard of King James, the lion of Howard, or the falcon-banner of Marmion. Thus the gradual wavering and the final fall of this banner are watched with a more lively interest at a distance from which sight is not lost of the general contest, and the sudden appearance of the warrior's masterless horse,

> Blood-shot his eyes, his nostrils spread,
> The loose rein dangling from his head,
> Housings and saddle bloody-red,

is more sudden and startling, than if the deed of the borderer, who bore him from his saddle, had been distinctly described. The latter incident also works up the situation of Clara to the most anxious pitch, when

> Eustace, maddening at the sight,
> A look and sign to Clara cast,
> To mark he would return in haste,
> Then plung'd into the fight.

Of the poverty of Virgil's conceptions of character, as compared with Homer, we have already commented. It is, therefore, but justice to express our admiration of the perspicuity, dignity, and good keeping, with which he manages his external circumstances, preserving, like a skilful painter, the due proportion between his salient and retiring points. In the dubious twilight under which Æneas and the Sibyl enter the portal of the Shades,

> *Quale per incertam Lunam, sub luce malignâ*
> *Est iter in sylvis, ubi cælum condidit umbrâ*
> *Jupiter, et rebus nox abstulit atra colorem,*

the shadowy images of evil Genii are blended in a manner more sublime and fearful (like Milton's image of Death) from their very indistinctness; and at the same time more perspicuous in relation to the general group, than had their several features been more clearly expressed. Nothing can be a finer instance of that bewildering obscurity, which ranks with infinity as a source of the sublime. Again, the momentary glance which Æneas takes of the entrance to the penal regions, presents images of horror more distinct, relieved by the fiery light of Phlegethon from the abyss where the rebel Titans are howling and clanking their chains:

> *Respicit Æneas subito, et sub rupe sinistrâ*
> *Mœnia lata videt, triplici circumdata muro,*
> *Quæ rapidus flammis ambit torquentibus amnis*
> *Tartareus Phlegethon, torquetque sonantia saxa.*
> *Porta adversa, ingens, solidoque adamante columnæ,*
> *Vis ut nulla virûm, non ipsi exscindere ferro*
> *Cælicolæ valeant, stat ferrea turris ad auras,*
> *Tisiphoneque sedens, pallâ succincta cruentâ,*
> *Vestibulum insomnis servat noctesque diesque.*
> *Hinc exaudiri gemitus, et sæva sonare*
> *Verbera; tum stridor ferri, tractæque catenæ.*
> *Constitit Æneas, strepitumque exterritus hausit.*

It is fitting to remark, that the terrific grandeur of this and similar passages in the VIth book of the Æneid, unmatched save by Milton as pictures of external images, could not have been thus concentrated save by a Philosophical and perfect acquaintance with the rules of that ἐνάργεια, in which we conceive Aristotle to have implied a tact analogous to that of the painter[*] in his management of light, shade, and grouping, and not confined to the mere perspicuous disposition of circumstances. In fact, so intimately connected is the power of which we speak with all the higher qualifications of Poetry, that it is impossible to discuss its effect without adverting to examples in which these also are displayed. The continuity of circumstances, for instance, so well preserved in *Chevy Chase*, is admirably adapted to meet that agitative sympathy of the Understanding to which we have alluded as a principal source of Poetical pleasure, and which when once wound up to its full pitch, resents the interruption of those minute particulars or irrelevant words and reflections, which obstruct the full career of action.

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[*] As for instance, (*suppositis supponendis,*)

> Fierce Marmion's arm, invincible in fight,
> Through border legions first let in the light;
> Stout Haliburton bites the bloody ground,
> And Pringle's heir gasps with a mortal wound,
> Scott, Laidlaw, Kerr, lie stretch'd upon the plain,
> And Ramsay speeds to Orcus' dark domain;
> But ah! while rag'd the warrior far and wide,
> The lance of Home transfix'd his mailed side,
> While Gordon's axe, with matchless strength addrest,
> Dash'd on his helm, and raz'd his falcon crest;
> He falls, he bleeds; to ruthless foes a prey,
> In dust and gore the groaning hero lay:

and thus at the rate of *mille versus stans pede in uno.*

[*] As for instance, Rembrandt, whose general effect is caught by the eye at the first instant, from his wonderful knowledge of *chiaro oscuro.*

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antial de-
ails when
ost proper.

It is evident nevertheless that occasions occur in Poems of continuous Epic action, best expressed by the Virgilian phrase of the *cardines rerum*, on which more circumstantial details may be fitly introduced; when for instance some great and spirit-stirring deed, pregnant with important consequences, is on the eve of taking place. These details, however, should be special preparatives towards the event for which the Poet pauses to collect his powers, and the reader his attention, resembling as it were the gradual gathering of thunder-clouds in the horizon, indicative of the approaching storm. An event of any magnitude is sufficient to justify greater minuteness of description in the introductory details, from which, if they be well managed, it derives additional dignity in its turn; while the suspense and curiosity of the reader are prolonged, and his conception of the circumstances of the crisis at hand rendered more clear. Thus in the *Siege of Corinth*, every preparative calculated to add an imposing terror to the Moslem attack is sedulously enlarged on in the forty-five lines composing the twenty-second stanza:

> ———— The trump, and the drum,
> And the mournful sound of the barbarous horn,
> And the flap of the banners, that flit as they're borne,
> And the neigh of the steed, and the multitude's hum,
> And the clash, and the shout, "They come, they come!"

Meantime, lest these accumulated details should prove tedious, the attention of the reader is fixed on the expected discharge of the culverin, which is to act as the signal of assault to the overwhelming force which they have depicted; and which winds up the stanza with the effect of an electrical shock,

> Silence—hark to the signal:—fire!

Homer has thus deliberately multiplied all the concomitants to the final appearance of his hero in arms which a grand and imaginative mind could suggest to swell the pomp of the event. The amnesty between the rival Chiefs, ratified by the stately eloquence of Agamemnon, the richest gifts and the most solemn sacrifices, —the arrival of the divine arms, from the glare of which the hardy Myrmidons shrink in dismay, while Achilles joyously views them with the gaze of an eagle on the sun,—the strength with which he shakes and poises a spear which no other Greek could lift, shaped for his father by the Centaur Chiron from the trunk of a mountain tree—his crest floating

> Like the red star, that from his flaming hair
> Shakes down diseases, pestilence, and war,

—and the rush of the marshalled host like a deluge to the field of battle,—all these lofty details are concentrated on one point, and finally wound up to a climax by the dauntless defiance of evil omens, uttered by the hero, which sounds like the trumpets' signal for the onset;

> ———————— So let it be!
> Portents and prodigies are lost on me;
> I know my fate, to die, to see no more
> My much-lov'd parents, and my native shore;
> Enough; when heav'n ordains, I sink in night;
> Now perish Troy!——He said, and rush'd to fight.

It must be owned that the elaborate description of the Vulcanian shield, which precedes the XIXth book of the *Iliad*, is somewhat tedious. Yet in this, and the methodical descriptions invariably given by Homer of the arming of his knights, it is probable that he "accommodated the shows of things to the desires of the mind," with reference to the propensities of his Age, as already adverted to. The same exciting curiosity with which the modern reader glances over the general features of the Moslem host preparing for the storm of Corinth, would, in a period when every man was occasionally a soldier, centre itself in the examination of the armour of proof worn by the Chief on whom the fortune of the day depended, and watch every movement as the prelude to the important deeds which he was about to perform. Or it may be, that Homer purposely intended to refresh the minds of his readers by the contrast of a lively picture of the varied details of social life, (like an agreeable landscape painted on the drop scene which is to draw up and discover the final dénouement of a Drama,) till his XIXth Book should burst on their imaginations with redoubled sublimity and interest.

Exemplified in the Odyssey.

With the character and purpose of the *Odyssey*, these details of every-day life (for which the Poem has been ignorantly censured) are completely in unison. By a happy comparison, this Poem has been likened to a still Summer evening, a sequel, as it were, to the meridian heat, and toil, and splendour of the *Iliad*, and answering to the evening of life which one of the most renowned Chiefs of that Epic Poem has now approached in the course of years. Thus the reader's imagination is kept fixed on those vivid pictures of primitive hospitality and good faith, of patriarchal justice and serene old age, of conjugal and filial affection, of simple habits of life, of rustic fidelity and rural ease, which naturally fill the mind of the Chieftain, as connected with the home to which the event of the Poem is to restore him, after an eventful life of battles and wanderings. Hence the details of the smooth stones on which the Pylian Elders and their Sovereign administered justice under the open face of Heaven; of the simple occupations and familiar sports of Nausicäe and her handmaidens; of the horticulture of the venerable Laertes, and even of the swine-pens and humble cares of Eumæus, are in strict character with the design and plot of the *Odyssey*; of which, perhaps, more than of any other Classical Work to which the student returns to refresh his recollections, it may be said,

> *Hæc decies repetita placebit.*

Nor are there wanting the romantic attractions of

> ———————— Antres vast, and deserts wild,
> And men whose heads do grow beneath their shoulders;

the atrocities of Polyphemus, the spells of Circe and the Syrens, and the perils of Scylla. But these the Poet has, with infinite judgment, toned down, as it were, and blended with the back ground, through the medium of the hero's own narrative at the cheerful board of Alcinous; that so the sympathy of the reader may rejoice with Ulysses over the memory of past sufferings, and anticipate the satisfaction with which he will recount the tale of wonders in Ithaca, rather than be excited by the actual occurrence of these to a degree inconsistent with the tranquil keeping of the Poem.

In Palamon and Arcite.

The Episode of the Temple of Mars, in *Palamon and Arcite*, is as remarkable for its descriptive force and admirable selection of circumstances, as for the manner in which, like the XIXth book of the *Iliad*, it works the reader's imagination up, by a well-employed delay, to the final event, the fortunes of the day depending on the answer of the Oracle. The blasting influence of the warlike Deity, extending to the very air and vegetation, the gates of adamant hewn by the God himself, and yielding only to the fury of the whirlwind, the massive walls illuminated only by a spectral Northern light disclosing dimly a shadowy crowd of murderous and appalling images, and "the rattling tempest" continually raging in the cold mountainous region, afford Dryden a subject in which he has excelled himself as the interpreter of our glorious old Chaucer.

Our remarks on the keeping and selection of Poetical images have necessarily led us, as will be perceived, into considerations connected with their more general bearing on the character and conduct of a plot, as the rules relative to both cases appear to rest on correspondent principles.

Relation of Allegory and Metaphor to Simile.

Those embellishments of style classed under the names of Allegory, Metaphor, and Simile, are obviously reducible to one head, as founded on analogy, and dependent on the correctness of that analogy for their whole force and beauty, as illustrations of the relation of two objects of our contemplation, or more, by the discovery of the same relation between a similar number of objects of a different class; a discovery agreeable at once to the Judgment and the Imagination, according to its accuracy and novelty. The original and most simple form of this analogy naturally suggests itself as embodied in the Simile, which stands in relation to Metaphor and Allegory as a plainly expressed syllogism does to the elliptical form of the enthymeme, and the combined chain of a process of reasoning. For instance, Homer plainly states the four terms, or more, of his analogy, in substance thus. "As two young oaks, on the top of a mountain, resist the tempest, so did Polypætes and Leonteus, in their exposed situation, resist the brunt of the Trojan charge." Here the analogy of the Simile, consisting of six terms, is kept up with accuracy, and yet with no apparent labour, the respective relations of things suggesting themselves to the reader at a glance. The dignity of the young Lapithæ is also preserved, and even augmented by an assimilation with natural objects of power and sublimity, all graphically true to the subject which they illustrate, and sufficiently brief in their expression to leave something to the Imagination; as the strength and beauty of these mighty forest trees, the sway of their limbs against the storm, like the arms of warriors repelling a host; the howling and whistling of the wind in contact with their branches, like the shouts and cries of the triumphant Trojans in their onset; and the fixed attitude of the two redoubtable Chiefs, like hardy oaks, on a post from which they must be torn up lifeless ere they yield a span of ground. One such instance as this is sufficient to show that a really perfect Simile will bear the minutest examination in more relations than that which the Poet may have expressed. On the contrary, the comparisons (in different parts) of the groans of Agamemnon, and the ease and copiousness of Ulysses's eloquence, to a fall of snow, (which illustration seems to have met with peculiar favour in Homer's eyes.) seem to us in both instances defective, inasmuch as they apparently consist of only two terms each—as thus, "Agamemnon's groans came as quick as the successive flakes of snow descend;" "The words of Ulysses fell as softly and copiously as a fall of snow." In this second instance, the relation between the first and second term is somewhat improved by the union of two links of similitude instead of one. But there seems no more ingenuity displayed in either case, than in saying that Agamemnon was as brave as a lion, or Ulysses wary as a fox, facts appealing neither to the Judgment nor to the Imagination.

It is rather singular that Virgil, whose general dignity and good taste are unquestioned, should in two instances have linked mean associations with characters of note and consequence, by an ill-advised selection of Similes. The comparison of Amata, flying about the palace under the excitement of warring passions, to a whipping-top scourged by contending boys into full whirl and hum, is undoubtedly most true to the eye, as well as accurately perfect in the relation of its several terms. It would have been invaluable in a Comedy or Satiric Poem, as a picture of a furious scold irritated to the top of her bent; but for this very reason it is just as improper when applied to the description of a mother-queen frantic at an ill-omened crisis impending over her Royal House.

A far more mean and wretched instance is found in the following Simile, illustrative, as it appears to us, of nothing but the hour of the night at which Vulcan arose, and hardly possible to arrange under four distinct terms, save by the assistance of the Cyclops and the female slaves.

——————Cum fœmina primum
Cui tolerare colo vitam tenuique Minervâ,
Impositum cinerem et sopitos suscitat ignes,
Noctem addens operi famulasque ad lumina longo
Exercet penso, castum ut servare cubile
Conjugis, et posset parvos educere natos,
Haud secus Ignipotens, &c.

which final *haud secus* appears to clench this unfortunate passage as a Simile to identify Vulcan with the careful semstress. Some critics have remarked on the affecting beauty of this image of the poor woman's anxious toils, not perceiving that were this even the case, a directly contrary train of association is required, when the vigorous labours of a God are the subject. It certainly requires a liberal share of undoubting classical prejudice, to discover any thing more affecting in the description, than the circumstances of an idle husband, sleeping off his *panem et Circenses*, a frugal and restless housewife, stinting her half-starved maids in their natural sleep, to feed his idleness, and the necessities of his squalid brood; in short, a combination of such circumstances as embitter the curse of Adam in low suburban life. And this in illustration of the munificence of the son of Jove, rising like a giant refreshed with sleep, to employ the strength of the brawny Immortals who forged thunderbolts like toys, upon armour which is to decide the fate of a Kingdom, and the fortunes of a Goddess-born Chief.

It is difficulty to draw the exact distinction between Simile and Metaphor as applied to Poetry; in fact, as we have already shown, there is no virtual difference between them, a Metaphor being only a Simile abbreviated in its expression, when the application and relation of the terms are obvious. Thus the rebuke of the Philosopher Anaxagoras to Pericles, as quoted by Aristotle in relation to this very subject, is capable of extension into the four terms or more of a Simile, but more delicately and pointedly worded than had the whole been expressed: "Those who make use of a lamp, Pericles, take care to supply it with oil."

It is, perhaps, not always necessary that the four terms should be distinctly implied. As an instance, where the beauty of the image is not impaired by a certain degree of this indistinctness, we may mention the short Psalm, "Behold how good and pleasant a thing it is," &c. which Lowth has so beautifully translated into Horatian metre.

It is hardly necessary to remark, that the use of the Simile is not adapted to the terse contentious character of conversation or argument, in which, however, the use of the Metaphor is often powerfully effective. And the slightest knowledge of etymology shows us that the greater part of prose words employed on every subject, save the visible and tangible objects before us, are, in truth, Metaphors in themselves, and implying a relation of four terms. But these considerations are rather applicable to the subject of Rhetoric and Language in general.

rigin of llegory.

Allegory may rather be considered as a prolonged Simile, or a series of Similes aptly fitted together, than as any thing distinct in itself. Its first origin may be naturally traced from the aspirations of imaginative minds, in the darkness of Heathenism, to realize in some distinct image their abstract conceptions of the mighty powers of Nature, and the still mightier and more mysterious faculties of the Soul, which even the light of Nature represented to them as "made in the image of God." Thus, the sublime fiction of Pallas springing in full armour from the brain of Jupiter, implied that perfect wisdom emanates from the intelligence of the First Cause, from whom also the qualities of strength, skill, beauty, courage, and the physical blessings of light and warmth, were derived in the imaginary personifications of Hercules, Mercury, Mars, Venus, Apollo, and Vulcan, the children of the same omnipotent ruler. Thus also the Legend of the Python slain by the arrows of Apollo, is held to refer to some pestilential marsh dried up by the rays of the Sun; and it is probable, that many other mythological stories, the key to which is now lost, were rather personifications of the workings of certain mental and natural powers, than the mere sports of fancy. The same inference will probably apply to the tedious extravagancies of the Brahminical Mythology, and the wild Runic fictions of the Scalds.

Hence, in time, the patent of Poetical creation was extended to Dryads, Oreads, River Gods, and other allegorical symbols of the secondary causes operating on the face of Nature. Thus far, indeed, the sources of Poetical pleasure were augmented and enriched, and the inherent love of sylvan beauty dignified.

buses.

But when, in later Ages, the same privilege was extended to Sciences* and abstract qualities, as well as to Provinces and Cities, an unmeaning medley was created, meriting the just sarcasm of Petronius, "that in his days it was easier to find a God than a man." It must be acknowledged that Claudian, who was particularly addicted to this species of ornament, excelled in its management as much as was consistent with the nature of his materials. Some of his personifications of Towns and Countries are introduced in a brief and characteristic manner which assists the reader's conceptions of the circumstances represented by the Allegory, and places them in a clear point of view. In a long-continued Allegory, however, the Poet runs great dangers, and must labour with great attention if he would avoid the fault of mixed Metaphor, or the absurdity of confounding the abstract with the tangible.† This Spenser has tolerably well avoided, and it would have been well had Dryden looked more to the example of the latter, when he represented a Hind talking polemics between her mouthfuls of grass, in his well-known apologue relating to the Catholic Church. But perhaps it is not far from the truth to conjecture that, in nine instances out of ten, the Poetry of Spenser is read merely for the sake of its scattered beauties, and that there are few works of equal merit, which can be so patiently laid aside at the hours of meals and rest, as the *Faerie Queene*, a Poem which all agree in praising. The causes of this (at least in our own view of the question) are natural, and applicable *à fortiori* to the mass of symbolical dulness which, as in the last century, was dragged into action to serve any given purpose of flattery with the least portion of imagination.

Causes of the dull effect of prolonged Allegory.

It is clear enough that in a continued Allegory, the personages must necessarily walk, talk, and conduct themselves in a manner addressed either to the sympathies of the reader, or his sense of the beautiful and sublime. Now although mankind are ready enough to surrender themselves to the Poet's illusion in favour of persons and circumstances, the like of which they can easily conceive to have existed and happened in real life, they are cautious in bestowing either interest or admiration upon things entirely *sui generis*, and owing their existence only to the professed labour of an ingenious brain. The same effect is produced, as if a large automaton could be so managed, by the help of ventriloquism and machinery, as to give a perfect representation of the part of Lear or Othello on the stage. The feeling of wonder at the ingenuity of the trick would entirely supersede any sympathy (if such indeed could exist for a moment in sober earnest) with the parental or conjugal feelings of the doll. The *Pilgrim's Progress* is almost the only successful instance of a continued Allegory kept up in prose, in which form perhaps this mode of writing conveys less of tedium to the reader. But here, independent of the skill and good management in the conduct of Bunyan's symbolic fiction, other merits present themselves, the discussion of which is foreign to our present matter. The *Vision of Mirza*, which possesses more of the true Poetical spirit than any professed Poetry by Addison, and may be pronounced in every respect perfect, cannot be considered as a continued and palpable Allegory of the class which we have described. Its outlines are touched with the lightness and delicacy which a visionary subject demands.

Causes of the interest conveyed by Fables.

The instruction and amusement afforded by well-chosen Fables, such as those of Gay, is universally acknowledged: and since these may, strictly speaking, be classed as Allegories, it appears necessary to explain the reasons why they produce an effect so contrary to that of such frigid fictions. The fact is this, that the symbolical picture of human actions is here represented not by abstract phantoms, but by real, tangible creatures, capable of pain and pleasure of the same sort, in many instances, which we ourselves experience, and approaching in their instincts so nearly to the reason of Man, as to create an involuntary idea of their responsibility. Thus,

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* *Mussabat tacito Medicina timore.* Lucretius.

† In spite of the good example set by Westmacott, in rejecting the ready aid of Fames and Britannias in his monumental group to the memory of Abercrombie, (an example in one or two instances happily followed,) the most atrocious instances of the fault in question are perpetrated still, according to order and measurement, at the cost of the public. Thus (speaking from recollection) a dying General is supported and comforted by the joint efforts of Britannia in Roman armour, and a light-infantry man in full regimentals, while Hercules stands by totally naked, and evidently doubting whether his own appearance is either decorous, or required for any possible reason.

for instance, the bite of a dog creates a momentary resentment against the animal, unfelt by the person who is equally hurt by falling against a stone. And whether such conclusions be warranted in strict reasoning or not, it is impossible to divest the imagination of the idea that the elephant is susceptible both of praise and remorse, that the monkey has a truly human delight in mischief, that a high-fed horse exerts himself in company from a feeling of emulation, and that the master-dog in a country town enjoys precisely the same kind of self-importance as the beadle. Thus no very difficult task is imposed on the fancy, in imagining brutes endowed with the power of expressing to each other their simple pains, pleasures, and perceptions, arising from such circumstances as they are commonly conversant with, and forming an abundant class of parallels to the analogous relations of Society. By this means an independent interest is created in the animal symbol itself, as for Æsop's poor hound, lashed in his old age for the failure of his well-tried speed and scent. But to preserve this interest, as well as to avoid absurdity, the truth of animal habits and character must be observed. Cocks and hens must not neglect their barley-corns to talk polemics, like Dryden's Hind and Panther; and though the grave Roman Historian assures us that an ox spoke at some momentous crisis, he has not the hardihood to add that he gave any political advice.

Of Hyperbole.

Of Hyperbole, Apostrophe, and such little semi-rhetorical aids to diction, it is necessary to say little more but that they are the constant resource of bad Poets, and, save in the case of the joint productions of Dryden and Lee, cautiously employed by men of genius. But Lee was mad, and Dryden was driven by necessity to suit the false taste of the times. It is obvious that no Hyperbole is implied in such marvels as are consistent with the plot of a Poem; for suppose Ajax and Achilles men of gigantic strength, and their feats are in keeping. Occasionally, perhaps, when the Poet's breast appears to labour with some mighty conception, such hyperbolical flights as the following (describing the forging of Æneas's armour) may even add grace to the context, though the limits between the tangible and ideal are somewhat confounded.

Fulgores nunc terrificos, Sonitumque, Metumque,
Miscebant operi, flammisque sequacibus iras.

It is difficult to say by what other means Virgil could have expressed the supernatural qualities of Vulcan's gift.

On the origin of Metre we have already offered such conjectures as appear to us most probable, nor is it our intention to enter analytically on those more minute discussions which may be better found elsewhere. As far as regards a general and practical view of the matter, it may be affirmed, that the respective fitness of different kinds of Metre to their usual subjects, depends very much on arbitrary and accidental causes, and that as long as the laws of mental association subsist, established precedent ought not to be departed from without some very substantial reason. It must be acknowledged that during the last century, the writers of our own Country adhered somewhat too rigorously to the canons of rhythm and cadence founded by Pope, and that the present School of English Poetry have successfully departed from a style which had become almost burlesqued by repeated abuses. But both Byron and Scott have strictly adhered to precedent, in reviving Metres existing before the times of Pope, and which that great man would probably have himself adopted, had he treated subjects of a nature not suited to that heroic couplet which he carried to the utmost pitch of perfection.

The choice of Comic Metres evidently depends on the whim and fashion of the moment, and cannot be gravely defined by any rule, when we recollect the peculiarly apt effect of Swift's Lilliputian Ode to Gulliver, pointed as it is by the trisyllabic verses adopted. But in regard to Metres appropriated to serious subjects, it may be doubted whether any more particular rule can be assigned, save that the length of each verse should be sufficient to admit of a full and musical cadence, and not extend beyond those limits which preserve its grace and compactness.

How little, after all, the effect of true Poetry depends upon the choice of any Metre possessing the proper requisites, may be inferred from the fact, that the same rhythm has been adopted, with the slightest possible variation, in Moore's *Last Rose of Summer*, in Anstey's *Bath Guide*, and in the following noble burst of Imagination occurring in the *Deformed Transformed*.

But the chase hath no glory,
  Her hero no star,
Since Nimrod, the founder
  Of empire and chase,
Who made the woods wonder
  And quake for their race.
When the Lion was young
  In the pride of his might,
Then 'twas sport for the strong
  To embrace him in fight;
To go forth, with a pine
  For a spear, 'gainst the Mammoth,
Or strike through the ravine
  At the foaming Behemoth;
When Man was in stature
  Like towers of our time,
The first-born of Nature,
  And like her, sublime!

The greater part of what may be observed on the subject of Epithets, relates to the consideration of words in general, with regard to their Poetical fitness. In their own peculiar capacity, as connected with the matter of the context, they are a means afforded by the structure of Language, of blending the idea of the thing described with another distinct idea of quality, action, time, magnitude, or relation, which the adjective or participle in question concisely suggests by a single word. Thus far, but with great modesty and caution, they may be used in simple Prose, as well as in Poetry and the more animated departments of Rhetoric. To the latter branches of style, a still more enlarged use of Epithets may be permitted for the purposes of contrast, climax, or amplification, and in all those indefinable cases where it may be necessary to give more strength and distinctness to an idea partly or wholly implied in the substantive with which the Epithet would connect it. Now if such Epithet be far-fetched or obscure, it embarrasses the rapidity of thought in the reader, which ought to keep pace with the Poet's words, and which it is its proper business to assist. If not exclusively relating to the circumstance, passion, or action described, it breaks the train of that thought by something wholly irrelevant, or though generally true, repugnant to that occasion. (As if Homer should say "the friendly Patroclus, or the duteous Achilles, rushed on the foe.") If merely the echo of an idea* fully and vividly implied in the verb,

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* As if the Poet should say, "the fierce tiger," "the bright sun," "the sylvan forest," or "the godlike Jove."

substantive, or any other part of the sentence, it lowers the whole context into dull tautology. Thus the use of Epithets in Poetry demands almost as much caution and judgment as in Prose. As an instance of a long passage, where not a single Epithet is introduced without adding some distinct idea of force and grandeur to the imagery, we may refer to the fifty-four lines concluding the IId book of the *Georgics.*

> *Ille etiam extincto miseratus Cæsare Romam*
> *Cum caput obscurâ nitidum ferrugine texit,*
> *Impiaque æternam timuerunt sæcula noctem. &c*

The passage in question may indeed be set in the same rank with the lines quoted by us as the description of the portal of Erebus; as equally remarkable for its selection of grand and striking images, and the display which its metre and cadences afford of the powers of the Latin hexameter.

In no respect, perhaps, is the Greek Language so remarkable, as in the facilities which its structure affords of expressing complicated ideas by single and expressive words; more peculiarly as regards the privilege of forming compound Epithets enjoyed by their Poets: a privilege exercised to no extent in any modern Language of any note, save in the German, which by its flexibility in this respect, its noble Teutonic cadences, and its abundance, may be said to approach more nearly to the Greek than any of them, in spite of its apparent roughness. Our own Language, though more abounding in pithy and hereditary compounds of the sort in question, than the French, Italian, or Spanish, has still often baffled the Poet's efforts to add to their number, as in the case of Campbell's expression, "the wolf-scaring faggot." The awkwardness of this word arises from the want of generality in the term "wolf." When a new compound is in this manner attempted, one of its parts ought to be inclusive of several classes of things,[*] or equally applicable to them: while the other serves to particularize the meaning, and thus a far-fetched and forced appearance is in a great degree avoided. Hence the same author's term of "battle-blade" is more allowable. We are recalled to the subject of Greek Epithets by the recollection of a forcible line in *Gertrude of Wyoming*, in which an image of terror is amplified by contrast and negation—

> Red is the cup they drink—but not with wine!

This, though reminding us of the successful use of the same imposing figure of Language by Æschylus, suggests also the concise manner in which the latter would have glanced at the

> Δέπας[†] ἐρυθρὸν, ἌΟΙΝΟΝ.

Thus the very dust before the walls of Thebes, becomes, in the hand of the Poet, a messenger of dread,

> Ἄναυδος, σαφὴς, ἔτυμος αγγελος.

Choice of words.

The choice of words in general, as adapted to the use of Poetry, may be considered in relation both to their sound and their import. It is almost superfluous to observe, that in this respect, as in every other connected with Poetry or Prose, perspicuity is the first duty of a writer who respects the patience of his readers, and desires to escape the imputation of either not understanding his own meaning, or wishing to hide its weakness by the favourite resource of the Sophists,[*] mystification.

Connection of Sound with Sense.

It is evident, from the pleasure afforded by instrumental Music, as well as the attention with which many persons listen to harmonious passages of a Language which they do not understand, that any striking combination of sounds has a distinct character of its own, and a power of suggesting a train of ideas corresponding with itself in the mind of the hearer. Hence nothing is more common than to find songs written expressly to suit favourite airs, which were originally composed as mere instrumental performances. It is therefore not beneath the attention of the Poet to cultivate in this respect the indispensable gift of a correct ear, and to shun, both as regards the structure of his verse, or the choice of individual words, any discord which the sense does not render unavoidable. In many cases an appropriate force is imparted to Poetical diction, by accommodating the sound to the sense, more especially when some vivid object of the external senses is to be described. The safest means of effecting this end, perhaps, consist in adapting the structure and breaks of the metre to the expression sought. Thus Virgil has without the help of any unusual word, hurled down a tower with stupendous force:

> *Aggressi ferro circum———.*
> *——————— convellimus altis*
> *Sedibus, impulimusque.*

The stone of Sisyphus, again, in the hands of Homer, seems to grate back from the summit of the hill, and gallop in thunder to the bottom, chiefly by his artful disposition of cadences; but perhaps in some degree from the appropriate sound of particular words. The passage is too familiar to need a quotation. When, however, it may seem expedient to adopt these minute verbal aids to their full extent, great caution is necessary to avoid the semblance of what is familiarly called "trick and jingle."[†] Even Mason, in his splendid

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The same rules which apply to adjectives may be equally laid down as to adverbs, which in fact are only a different technical form of expressing quality, magnitude, &c. &c.

[*] Thus πολὺς, μέγας, and words of the like general import, are the bases of whole hosts of Greek compounds. It is evident, however, that the Greeks claimed a peculiar exemption from the rule in question, (which we state as in our opinion warranted by general induction.) The phrase of Æschylus, βοᾶ πεδιοπλόκτυπος, perfect as it is in sound and sense in the first chorus of the Ἑπτὰ ἐπὶ Θήβας, does not, to the best of our recollection, occur in any other Greek Classic of note, and was probably coined in the fervour of composition.

[†] As a deprecation to the manes of the fierce old Bard, we beg to acknowledge our forgery.

[*] See their well-known precept of Σκοτιζὸν.

[†] Bürger, with the true honesty of the *Deutsche Biedermann*, has avowedly used interjections coined by himself to express the ring of a bell, and the tramp of the spectre horse, in his Ballad of *Leonora*,

> *Und horch! und horch! den Pfortenring*
> *Ganz lose, leise,* klinglingling!

Again,

> *Und* hurre, hurre, hop hop hop!
> *Ging's fort in sausendem Galopp.*

The precedent is rather dangerous, and only set by this author in one or two instances of his Ballad metres. But it may be doubted whether such a bold-faced innovation on the rules of Language be not more graceful than the covert artifices to which we allude, when carried too far. It is possible that Bürger, whom from some circumstances in his Works we should guess to have been familiar with our Language, may have read Stanihurst's *Virgil;* and in this case he has afforded a very softened likeness of the "rounce robble hobble," and

> Loud rub-a-dub tabering with frapping rip-rap of Ætna,

which Massinger ridicules in his *Virgin-Martyr.*

Druidical Ode in *Caractacus*, has not escaped this fault. The "apt alliteration's artful aid," is too prominent in several lines, but more particularly in the following,

> I spied the sparkling of his spear.

In the selection of these words he could hardly have carried his zeal and accuracy so far as to copy purposely the precedent of the Welsh Bards, who substituted alliteration for rhyme: and his imagery certainly does not require the aid of quackery on this or any other ground.

Force of association as relative to words.

Experience, however, teaches us, that the effect of words on the Imagination depends not so much on their sound, as on the habitual associations with which chance, education, or use has connected them. Thus, as far as mere cadence and euphony are concerned, the respectable patronymics of Hayward, Price, Stunt, and Meux, are precisely similar to those of Howard, Bruce, Blount, and Vaux. History has, however, connected deeds of knightly and heroic achievement with men who chanced to bear the latter class of names, which consequently shine to an English ear with undiminished dignity by the side of such gallant trisyllables as Gonzalez,* Wallenstein, or Colonna.† Nor again can these foreign names claim any natural superiority of sound over "Barbara," "Camestres," or "Baralipton," the butts of scoffers at the Schools. The fact is, that they cannot be heard without instantly recalling a host of romantic recollections of the days when they served as a spell to armies and nations.

The same rule may be applied to all words in regard to their fitness for the uses of Poetry. It will in the first place be readily allowed, that Aristotle has argued rightly in his contemptuous refutation of the hypercritic Ariphrades,‡ as to the propriety of such words and collocations of words in metre, as are unfitted for ordinary conversation. We might perhaps add, that it is as inconsistent to reject such aid in a form of diction purposely cast in a different form from Prose, as to perform a part on the Tragic stage in an ordinary hat and coat.

Rules as to the choice of words in Poetry.

But as it is equally true that numbers of words used in the most familiar converse, are also perfectly Poetical, we will assign to the best of our power the reasons accounting for this obvious fact, as well as a few general rules to be observed in avoiding the suggestion of mean and prosaic associations; premising, that even if words are not positively the medium through which many persons think and argue during their lives, they are at least, when not mere particles or links of meaning, each the index to some point of knowledge, or impression of the feelings, and in some instances, the key to long trains of thought.

1. A word of very extensive and generic import, when used in its simple sense, and implying nothing in itself mean, is as it were the common property of prose and verse, and can hardly, under any circumstances, be positively prosaical. Thus "kill,"§ though it is used by poulterers and pig-butchers, creates no idea inconsistent with Poetry, though for the reason stated, "slay" is somewhat better, as being equally perspicuous and less common. But supposing a character to speak under the influence of intense passion, the more homely term would be the most fitting, provided it were not actually mean.

2. Those modified expressions which good breeding renders necessary in Society, should for that very reason be rejected in Poetry, as tending to lower and qualify its bold, decisive meaning. Thus "plain," as applied to person, is not so Poetical as the phrase "hideous," which may express the sensation created by a monster or demon. A witch may be Poetically called an "ugly old woman," but not a "plain elderly female." In short, no word should be used in serious Poetry, which can recall the ordinary chit-chat of the drawing-room, or, still worse, the pathos of newspaper eloquence.

3. For the same reason, all terms peculiar to familiar relations or occurrences of life should be equally avoided. Thus the word "handsome" in its primary meaning, as well as its secondary, suggests agreeable ideas as to the liberal conduct of a man in business, or his personal advantages in a ball-room, but is not on that account Poetical. The term "beautiful," though occasionally applied in both senses, is more proper for verse on account of its generality. Thus also all terms relating to trade, commerce, profession, or mechanical operations of any sort, when not very comprehensive, must be rejected. The phrase used by Dr. Johnson,

> ———— whom to beds of pain
> Arthritic tyranny consigns,

is not redeemed by its high sound from associations with the desk of the pedant and the dissecting-room of the surgeon; in fact, it seems just the ambitious attempt which an ingenious young apothecary would make to celebrate, like Lucian, *The Triumphs of the Gout* in his most sonorous manner. Besides the word is unintelligible, save to a Surgeon or a Grammarian. The phrase in *Hamlet*, of

> The fat weed that rots on Lethe's *wharf*;

reminds us involuntarily of barges and coal-sacks, on the point of that solemn disclosure which the Royal Ghost is about to make. The line also occurring in some version of Horace, "done into English by an eminent hand," unfortunately blends with the climax of the image represented by the original, the idea of a joint-stool giving way under the hero of the stanza,

> He unconcern'd could hear the mighty *crash*.

But, perhaps, these apparent absurdities* are only occasioned by the gradual alteration of the shades of Language produced by time. A still more unlucky instance is to be found in a Poem in which the language usually matches the conceptions. It is obviously caused by the author's ignorance of vernacular English: a defect, however, which ought to have rendered him cautious as to the coinage of new words.

> And as his thievish fancy seem'd to hear
> The *nightman's* foot approach, starting alarm'd,
> And in his old, decrepit, wither'd hand
> That palsy shook, grasping the yellow earth
> To make it sure.
>
> Pollok's *Course of Time*, book iii.

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* Count Fernan Gonzalez of Castile, second only to the Cid in his deeds against the Moors, according to Spanish Legends.

† The redoubted Prospero.

‡ "Ariphrades, too, ridicules the Tragedians for using such expressions in Poetry as no one would use in Prose, as *δωμάτων ἄπο*, instead of *ἄπ οδωμάτων*, &c. Now it is exactly because they are *not commonly used*, that such expressions impart dignity to the diction. *Of this however he was ignorant.*" Arist. *Poet.*

§ So of the words man, beast, pity, fear, anger, hatred, jealousy, &c. &c.

* The same may be observed of the apparent homeliness and vulgarity of the translations of Homer by Hobbes and Chapman, both men of unboubted talent.

No person, save the most grossly dull and ignorant, is likely to use any word in serious Poetry, approaching in the slightest degree to what is styled a "catch word," "slang expression," or "cant term." But, in fact, such words are almost equally unfit for the most trivial description of Comic Poetry above the level of the ballads sung at fairs. It must be borne in mind that the Science of cant terms was originally invented by common cheats and robbers, as a means of keeping their consultations secret. At present, in all its different shapes, it furnishes to persons of defective powers a technical substitute for humour and knowledge of the world, which often deceives the inexperienced. When, however, its phrases are tested by the ordeal of verse, their baldness becomes too conspicuous to be tolerated. And it may be observed, that the most humorous Poems[*] of our present day are couched in the purest English, adapted to give greater pungency to the allusions by its terse gravity.

4. The employment of words of studied simplicity, and of such as are far-fetched and high-sounding in proportion to the sense, are faults equally to be deprecated. Whether as regards the arrangement of his periods, or the choice of his phrases, the Poet who aspires to carry his readers along with him ought, at least, to appear to be thinking of his subject, and not of himself. Any thing bearing the semblance of affectation destroys the impression of truth, vigour, and earnestness, which should be produced by the fervour of composition. More particularly ill-timed and offensive are words of the kind to which we allude, when put into the mouths of imaginary speakers, and therefore professing to be an imitation of something actually uttered by another.

> Tis the *fire-shower* of ruin, all dreadfully driven,
> From his eyry, that *beacons* the darkness of heaven.
>
> *Lochiel's Warning.*

Now Cassandra, amid her wildest ravings in the *Agamemnon* of Æschylus, does not abuse the privilege of second sight in order to coin new language, but contents herself with dark allegorical allusions, and such strong verbal metaphors, as give force and dignity to her prophecies. When indeed a metaphor can be conveyed in one strong word, which instantaneously suggests the four terms of the comparison, as a "cleaving" curse, an "eating" sore, this concentration of meaning has a highly Poetical effect.

A similar concentration of meaning is afforded by words, which suggest certain trains of thought connected with National prepossessions, early partialities, or such accidents as have become by habit a part of the reader's nature. It may be truly said, indeed, that most words convey by association more than the idea which they simply express, and that many in the commonest use suggest the complicated relations between two or more persons or things. But the terms of which we are speaking stand as a sort of Historical indices of many circumstances which nothing less than a long narrative can clearly describe; and are untranslatable from the Language in which they were couched, as well as unintelligible to those who have acquired only the verbal mastery of it. Thus, with the Romans, the words *patrii lares*, *prisca fides*, and *gravitas*, suggested certain hereditary things and qualities consecrated by a thousand glorious recollections of the virtuous days of the Commonwealth. In the mouth of the meanest citizens they were pronounced with the consciousness that he was a Countryman of Cincinnatus, and an inheritor of the Institutes of Numa Pompilius. Thus, also, in our own Language, the terms of "Knight, Sultan, and Musulman," are less Poetical than their synonymes of Paladin, Soldan, and Paynim, inasmuch as the latter words suggest the relation in which these personages were placed, at a period from which we date the origin of our National Chivalry.

Use of proper names.

We have already remarked on the effect of well-chosen proper names in this point of view, as distinct from any advantages which they may derive from euphony. The names of places marked by any grand Historical event, bring to the recollection at a glance, the separate actions of a number of distinguished persons, while the name of a great man similarly suggests the history of his individual deeds. The same pregnant import may sometimes be conveyed in a mere epithet. It has been remarked by travellers in Norway, that the phrase *Gamlle Norgè*[*] seems to awaken in the natives a degree of warmth and veneration, which a stranger, however partial to his own Country, can hardly comprehend: that when pronounced at their convivial meetings, it seems to embody the essence of all which they love and prize. The reason should seem to be this, that the national pride of a Norwegian is exclusively connected with the Ancient History of his Country, as the Temple of the Northern Mythology, and the hive from which issued the most princely and unconquerable Tribes of modern Europe. Feeling that his native qualities are still undebased by slavery or luxury, and conscious that the name of his Country is a blank in Modern History, he delights to contemplate it in a relation identifying himself as the Countryman of Rollo, and the kinsman of Tancred and Guiscard.

The effect of a mere selection of well-known chivalrous names, may be remarked in the following passage from Sir Walter Scott's *Lord of the Isles:*

> Strong Egremont for air must gasp,
> Beauchamp undoes his visor-clasp,
> And Montague must quit his spear,
> And sinks thy falchion, bold De Vere!
> The blows of Berkeley fall less fast,
> And gallant Pembroke's bugle-blast
>   Hath lost its lively tone;
> Sinks, Argentine, thy battle-word,
> And Percy's shout was fainter heard,
>   "My merry men, fight on!"

Thus, also, Horace has called up a train of agreeable and varied classical images by the mere enumeration of names of places distinguished by Historical or Mythological fame:

> *Laudabunt alii claram Rhodon aut Mitylenen,*
> *Aut Ephesum, bimarisve Corinthi*
> *Mœnia, vel Baccho Thebas, vel Apolline Delphos*
> *Insignes, aut Thessala Tempe.*
> *Sunt quibus unum opus est intactæ Palladis arcem*
> *Carmine perpetuo celebrare, et*
> *Undique decerptæ frondi præponere olivam.*
> *Plurimus, in Junonis honorem*
> *Aptum dicit equis Argos, ditesque Mycenas.*
> *Me nec tam patiens Lacedæmon,*
> *Nec tam Larissæ percussit campus opimæ,*
> *Quam domus, &c. &c.*

In the due selection and use of this class of words, nothing more is required than a certain degree of good

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[*] A better instance cannot be quoted in a minor way, than the *jeu d'esprit* entitled *The Ball-room Belle,* attributed, we believe, to Mr. Praed.

[*] Old Norway.

taste and judgment, nor can they be considered in any higher point of view than as mere condiments to the solid subject-matter of Poetry. In Oratory, their unrestricted employment is still more obviously offensive. The allusions which they convey may aptly wind up a peroration for which the hearer's mind is prepared by argument, but become mere catchwords when substituted for that argument.

Whether there be periods of progress and decay in National Poetry.

It should seem a prevailing belief, that in National Poetry, as well as in National prosperity, there is a certain fixed period of progress and decline, a culminating point as it were, up to which, as in the Augustan Age of Rome, the Art of Song is gradually improved and developed, and beyond which no efforts of individual genius can rescue it from degradation.

This opinion we conceive to be greatly founded on accident and association of ideas. As long as a Language is spoken in its original purity among a people whose moral character is not brutalized by oppression, or corrupted by luxury, so long a fair field lies open to Poetry and Literature in general. Meantime the coincidence of two or three remarkable men may lend a reputation to a particular period of time, which is reflected on those smaller competitors in the same department, whom their example may have drawn forth, as well as on those of anterior date, on whose efforts they have improved. The external circumstances most likely to produce as well as to illustrate such an era of Literature, should seem to consist in some great and favourable political change of affairs, from the excitation of which the public mind is beginning to subside, or from some gradual progress of important events, which may stimulate without utterly absorbing its attention. A state of uninterrupted war, or of profound prosperity, are equally unfavourable to the developement of imaginative genius; the latter perhaps in the higher degree of the two. Refinement, when arrived at its height, is apt to engender a sickly and self-indulgent spirit tending to smother those nobler passions which form the material of true Poetry. The arts of conversation and policy, whose tendency it is to teach Language as much to conceal, as to express, the real thoughts of Man, pervert that Language from the character of truth and nature which it originally bore; and by engrafting it with foreign or artificial phrases, render it incurably prosaic. At the same time many small Poets arise, whose temporary reputation, obtained by conformity to the fashion of the day, either damps original genius, or tempts it into the beaten track. Such are the causes which appear to us as influencing the decline of National Poetry, when a Country has reached its zenith of luxury and prosperity, previously to which, its fluctuations seem greatly to depend on accident.

Effect of Knowledge not prejudicial to Fancy.

It is maintained by some, that the progress and diffusion of Knowledge has in itself a tendency to destroy all food for the Imagination, by correcting the errors of Fable and Tradition; that the wonders of Fingal's Cave, when explained by the theory of basaltic fusion, and the legends of Fairies and Enchanters, when disproved by the light of Reason, lose the dignity which attaches to the *ignotum pro mirifico*, and act as powerlessly on the Fancy as a phantasmagoria exhibited at noon-day. We rather conceive, on the contrary, that in proportion as such matters have lost their hold on the serious Belief of mankind, they have gained it over the Imagination. When they really were part and parcel of popular credence, they probably excited too vital an interest to be treated otherwise than as subjects of grave discussion, as would in the present day be the case with any newly-discovered phenomena in Australia or the North Sea. Now, however, they are mellowed down by time, like old wine, to a state more conducive to enjoyment than when they retained their first crude strength and body. The playful interest with which a modern reader surrenders himself (as when perusing the *Bridal of Triermain*) to delusions which after all do not exceed the privileged bounds of fiction, is directed, not only to such delusions in themselves, but also to the impressions produced on those to whose business and bosoms they came home. With a feeling allied to that with which he recalls the recollections of his own infancy, he thus appears to commune with the Spirits of his ancestors in some pleasant land of dreams; considering their traditions less as the History of facts than as the History of the minds of those who believed them as such.

Operation of Time in maturing Poetical subjects.

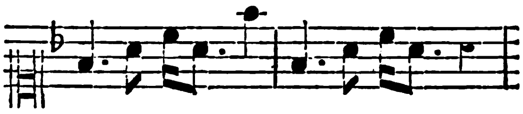
From similar reasons, events of any great magnitude become by a natural process more adapted to the purpose of Poetry when the strong interest which they occasion has subsided. The extraordinary and rapid political changes, for instance, which many of the present generation have beheld for the last forty years, still present themselves to the mind's eye in detached masses, foreshortened as it were by their nearness, and tinged with the local colouring of our passions and prejudices. Many centuries hence, when only the leading features remain, softened down by the mist of time, their magnitude and relative proportions, as compared with History in general, will assume a clearer and more intelligible outline, better adapted to the workings of the Imagination, as a mountain of predominant height is beheld to the greatest advantage at a considerable distance. Thus it is that Time, which ripens by slow degrees the secret stores of the Earth into precious metals, continues also to prepare new matter for the Poetical efforts of future Ages, confuting the doctrine that in Imagination, as in matter of fact, "there is nothing new under the sun."

MUSIC.

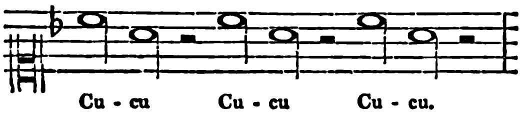
The art of combining sounds agreeable to the ear was among the earliest of the Sciences; with the Ancients the term had a much more extensive signification than it now carries with us. Under the term Music were comprehended not only that Science to which it is at present confined, and also the accomplishments of Dancing, and of Acting, but even Poetry and the whole circle of Sciences. According to Hesychius, the Athenians understood the term in this latter sense, and a modern Musician would have us believe that in Music is to be discovered the governing principle of all the proportions, not less than the foundation itself of all the Sciences.

Its origin.

The origin of Music must from its nature have been remote: this, however, is not the place for examining the claims of Mercury to the invention of the lyre; nor whether the Greeks were indebted to Cadmus, when he eloped from Phœnicia with Hermione, or Harmonia, which would fabulously establish the knowledge of it in that Country; nor whether Amphion, as Plutarch states, was the person to whom they were obliged for its invention. Neither is it of consequence here to inquire into the claims on that head of Apollo, Chiron, Demodocus, Hermes, Orpheus, and others; nor even that of Tamiris, the reputed inventor of Instrumental Music. These, or the greater part of them, preceded Homer. Others, such as Lasus, Melnippides, Philoxenus, Timotheus, Phryneus, Epigonius, Lysander, Simmicus, and Diodorus, have the reputation of having brought it to a considerable degree of perfection. It may almost be assumed that Vocal Music preceded that of instruments, and it is most probable that the natural elevations or depressions of the human voice in expressing the different passions of the mind, as well as the attention which would be naturally directed to the modulated song of the bird creation, would indicate the facility of so regulating the human voice as to suggest the elements of Melody. A portion of the song of the blackbird consists of true diatonic intervals, and may be thus expressed:



The note of the cuckoo is well known to be



gress.

A love of protracted and inflected sound differing from that of Speech is implanted in mankind throughout the Globe. Hence the progression would seem likely to the Music of wind instruments, which Lucretius has beautifully described in the following lines:

> *At liquidas avium voces imitarier ore*
> *Antè fuit multò, quam levia carmina cantu*
> *Concelebrare Homines possint, aureisque juvare:*
> *Et Zephyri cava per calamorum sibila primum*
> *Agresteis docuêre cavas inflare cicutas.*
>
> Lib. v. v. 1378.

The next step in the progress of the Science would be to Musical sounds produced by the aid of strings: this, Vitruvius, in his Treatise on Architecture, has called to his aid even for the purpose of ascertaining the proper tension of the ropes used in the catapultæ and balistæ. Instruments of percussion, such as drums and some other military instruments, would find their type in numberless hollow and even solid sonorous bodies in Nature which emit sounds, and those frequently far from disagreeable, on being struck by another solid body.

Could we implicitly rely on the statements of the early writers, either the Music of the present Age has degenerated in an immeasurable degree, or the senses and passions of Man have altogether changed. Aristotle, who appears to have written mainly with the view of combating the doctrines of Plato, nevertheless agrees entirely with him in respect of the influence of Music on mankind. Polybius tells us that the Arcadians, who inhabited a cold and inhospitable Country, could only be civilized through the medium of Music; and further, that the inhabitants of Cynetus, who neglected the cultivation of that Science, surpassed in cruelty all the rest of the Greeks. Athenæus assures us that the promulgation of laws both human and divine, the knowledge of all that related to the Gods, to heroes, and to the deeds of illustrious men were written in verse, and publicly sung with an accompaniment of instruments; a practice of which, as we learn from the Scriptures, was conformable to that of the Israelites from the earliest period of their History. Sensibly, however, as even to this day some are affected by the powers of the Science, the time seems passed when a Timotheus could excite the passions of another Alexander by employing the Phrygian, and allay them by the use of the Lydian mode. It cannot, indeed, be denied that the national Music of every Country has a direct influence on the passions of its inhabitants; than which a stronger instance cannot be adduced than that it was forbidden, under penalty of death, among the Swiss mercenaries employed on foreign service, to sing or play the celebrated *Rans des Vaches*, because of the melancholy it always produced, a circumstance which must be familiar to our Musical readers. Nor are other Countries without those melodies which are capable of raising and depressing the spirit of their inhabitants. "What," says Burney, "the ancient Music really was it is not easy to determine, and the whole is now become matter of faith; but of this we are certain; that it was something with which mankind was extremely delighted; for not only the Poets, but the Historians and Philosophers of the best Ages of Greece and Rome are as diffuse in its praises, as of those Arts concerning which sufficient remains are come down to us to evince the truth of their panegyrics."

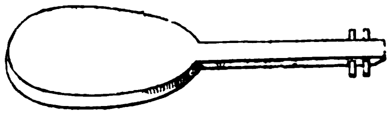
Egyptian Music.

Egyptian.

However rude and artless the first attempts in Music must have been, and little as was the probability of its having been perfected by the first cultivators, yet we are told by the ancient Poets and Historians that by them its miraculous powers were most successfully exercised, though it is not an easy matter to determine who they might have been. Herodotus, in his *Euterpe*, speaks of the Egyptians and Phrygians in regard to their respective antiquity; but neither concerning the Phrygians, nor the Phœnicians, undoubtedly a most ancient race, can more than conjecture be now offered; we shall proceed therefore at once to a succinct account of the Music of the Egyptians, whose monuments still present to the traveller indisputable proofs of their Religion and Arts. It would be vain to attempt its History from a higher source.

Though Diodorus Siculus has asserted that Music was prohibited by the Egyptians, as not only useless but even noxious from its tendency to make Man effeminate, we must oppose to his assertion the account of Plato, who travelled in Egypt in order to become acquainted with its Arts and Sciences. It is, moreover, observable that Herodotus, also a traveller in Egypt more than three hundred years before Diodorus, says, that it was used in their festivals and Religious ceremonies. Diodorus, indeed, contradicts himself, inasmuch as he tells us that Music and the Musical instruments were the inventions of the Egyptian Deities, Osiris, Isis, Orus, and Hermes, and that all the great Poets and Musicians of Greece visited that Country to improve themselves in the Arts. Strabo says, that the Egyptian children were taught letters, the songs appointed by the law, and a species of Music directed by the Government exclusive of all others. It should not be forgotten also that the Greeks, who had a propensity to claim the merit of every important invention, confess that the greater part of their Musical instruments were of Egyptian origin. Such are the triangular lyre, the monaulos, or single flute, the cymbal, or drum, and the sistrum, an instrument almost universally found on the monuments of the Egyptians. Every person acquainted with History will remember that among the Egyptians all professions were hereditary. The same practice existed with the Hebrews; and we are told by Herodotus, that the Lacedæmonians, who were by origin Dorians, so far pursued the system of their progenitors, that their Musicians were all of one family, and that their Priests, like those of Egypt, were initiated in Physic, Music, and Religion.

On the well-known Guglia Rotta, at Rome, which was placed by Augustus in the Campus Martius, after he had reduced Egypt to a Roman Province, among other Hieroglyphics is to be seen a Musical instrument of two strings, having a neck very similar to the calascione, still in use in the Kingdom of Naples. This species of instrument, therefore, must be considered of very high antiquity, and it is to be observed, that being furnished with a neck it was capable of producing many notes; inasmuch as if its strings were tuned in fourths, we have a series of sounds termed a heptachord by the Ancients. If, like those of the calascione, they were tuned in fifths, we have an octave, or two disjunct tetrachords, a power which, from all the remains of Greek sculpture, does not appear to have existed till a comparatively late period; indeed, Montfaucon, who examined the representations of nearly five hundred ancient lyres, harps, and citharæ, asserts that he had not found any in which a contrivance was apparent for shortening strings by a neck and finger board during the time of the performance. It appears, therefore, that the mode of extending a scale and of producing many sounds from few strings by the simplest means, was known to the Egyptians. It would exceed our limits to attempt fixing a date for the instrument thus alluded to. The literature of Egypt may even at this late period receive elucidation from the extraordinary and brilliant efforts of a Champollion. We shall here merely observe, that though more remote periods have been generally assigned to the monuments of the Egyptians than modern travellers and antiquaries have proved were due to them, yet the specimen in question is of sufficiently early date to afford ample room for speculation.



The lyre.

One of the secondary Gods of Egypt, who received divine honours for his extraordinary talent, was the Mercury surnamed Trismegistus: to him is attributed the formation of a regular Language, and many other matters important to mankind. Apollodorus attributes to him the invention of the lyre. The tale appears and doubtless is a pleasant fable: Mercury, as he walked along the banks of the Nile, after an inundation, which had deposited a great number of dead animals on its banks, struck his foot against the shell of a tortoise, whose cartilages by desiccation had become sonorous, the points of their original insertion in the shell remaining still fixed. This is said to have suggested the earliest idea of the lyre, which undoubtedly was first constructed in the form of a tortoise. To the first instrument of this sort three strings appear to have been given. The ancient writers on Music have supposed that the three sounds of these strings were E, F, and G, but Boethius makes the number of strings four, and says they were tuned thus, E, A, B, *e*; though this mode of tuning is generally supposed to have been the invention of Pythagoras, and at all events appears to have been introduced into Greece by that Philosopher.

To the dichord and trichord, which may be satisfactorily traced from Egypt, a claim is made by many for the addition of the monaulos, or single flute, which was crooked, and bore the Egyptian name of photinx. In form resembling a bull's horn, it is seen in numberless remains of ancient sculpture. Apuleius, in speaking of the mysteries of Isis, describes the crooked flute as held by the performer with the crook turned towards his right ear. That the Egyptians possessed the use of many instruments, other than those above recited, is clear from the original representations of them that have reached us, and particularly from those found on the walls of the celebrated tomb of Osymandyas at Thebes, whose stupendous remains have been described as exceeding more than half a mile in length. This sepulchre has been assigned to a period full two thousand years before Christ.

But the most convincing proofs of the progress and successful cultivation of Music among the Egyptians are to be found in the sepulchres of the Kings of Thebes, in which we find four varieties of the harp, the smallest with four strings, and the largest with thirty-eight strings, according to the representations by Denon. The action of the figures playing on two of these harps indicate very considerable execution on the instruments;

Music. Egyptian.

and if the figures moreover be used as a scale by which the instruments may be measured, it would appear that they were superior in size to those used in the present day. Among the representations in these remains we also find an instrument very similar to the Spanish guitar, except that the neck is longer. Dr. Burney has ventured some conjectures on the tuning this harp, on the authority of representations furnished him by the celebrated Bruce, but on these no reliance can be placed. Bruce gives but thirteen strings to the same harp on which Denon has bestowed no less than twenty-seven. And the form of the frame in the drawing by the former bears so small an appearance of Egyptian workmanship, that we must rather rely on the information and drawing of the French traveller.

erfection.

The Arts whose origin and perfection are to be found in this nation at a very early period, doubtless flourished whilst it was free, or at least under its own Kings. But after Psammenitus, the last of them, who was conquered by Cambyses 525 years before Christ, it was subjected to a foreign yoke. Its Arts and Sciences then disappeared, or rather seemed not exclusively to belong to it. However much the Ptolemies may have appeared to patronize them, and especially Music, yet under their sway, the Arts were those of Greece, from which Country their professors were imported. Under these Sovereigns, who invited artists and learned men from all quarters to the City of Alexandria, Music was doubtless much esteemed and cultivated. Athenæus, in his description of a feast of Bacchus, celebrated by Ptolemy Philadelphus, describes the band as consisting of six hundred Musicians, among whom were three hundred performers on the lyre. The seventh Ptolemy having put to death a great number of the inhabitants of Alexandria, and banished such others as were attached to his brother, whose crown he had usurped, filled his dominions with Grammarians, Philosophers, Geometricians, Physicians, Painters, Musicians, and others of that class, so that the Arts again flourished in Egypt; and so great, according to Athenæus, was at that period the taste for Music among its people that there was scarcely even a labourer in the vicinity of Alexandria who was not master of the lyre and the flute.

The father of Cleopatra, who was the last of the Ptolemies, took the title of Auletes, or flute-player, from his passion for that instrument. He thought so much of his talent on it that he established Musical competitions in his Palace, and disputed the palm with the greatest Musicians of the Age. Such was the state of Music in Egypt up to the ruin of Cleopatra's fortunes, an event which at once terminated the Empire of the Egyptians and their History.

Hebrew Music.

Burney observes with much truth, that notwithstanding the great labours of the early Fathers of the Church, notwithstanding the learning and diligence of numberless translators of and commentators on the Holy Scriptures, little can be gleaned for a History of Jewish Music save what is found in the Scriptures themselves. The great antiquity of the Hebrews, and the little communication which they had with other nations, renders it next to impossible to expect any illustration of it from contemporary foreign writers.

Music. Hebrew.

The translators of the Bible have been very confused with respect to the Musical Instruments of the Jews, for in about twenty times in which תף occurs in the Hebrew Bible, it is as often translated *timbrel* as *tabret*, a matter not a little perplexing; so again the word נבל, which Harmer, from its signifying a vessel made of a goatskin, conjectures to have been a species of bagpipe, is by our translators rendered by the word *viol* in *Isaiah*, ch. v. ver. 12, and in four other places, whilst its common translation is *psaltery*. To Jubal, sixth descendant from Cain, is attached the reputation of being "the father of all such as handle the harp and organ." The original כנר seems to have been a species of harp, but the word עגב, here translated organ, from its meaning to be set or joined upon another, was probably a number of pipes joined together resembling the common Pan's pipes, which is known to be an instrument of remote antiquity. Till upwards of six hundred years after the Deluge, the Scriptures do not record the practice of Music, but in *Genesis*, ch. xxxi. vocal and instrumental Music are mentioned, when Laban says to Jacob, "Wherefore didst thou flee away secretly, and steal away from me, and didst not tell me, that I might have sent thee away with mirth and with songs, with tabret and with harp?"

Next in order occurs the Song of Moses after passing the Red Sea, and the assistance on this occasion of Miriam the Prophetess, who "took a timbrel in her hand, and all the women went out after her with timbrels and with dances." During the period of the administration of Moses, no other Musical instruments are mentioned than trumpets and timbrels, and the latter only in the passage in which Miriam is concerned. The trumpets of rams' horns at the siege of Jericho, were most likely nothing more than signals for the assailants to march and shout, and by clamour to terrify the enemy. About fifty years after the Song of Deborah and Barak, we find the unfortunate offspring of Jephtha proceeding to meet her father after his victory over the Ammonites (*Judges*, ch. xi. ver. 34.) with timbrels and with dances; from which period until Saul was chosen King, about 1095 before Christ, the Bible has no reference to Musical instruments except the trumpet on military occasions. At the time at which Samuel anointed Saul, and on many subsequent occasions, there seems to have been a union of Music with prophecy. "David, with the Captains of the host, separated to the service of the sons of Asaph, and of Heman, and of Jeduthun, who should prophesy with harps, with psalteries, and with cymbals." Again, when the Kings of Israel, Judah, and Edom, with their armies were in danger of perishing in the wilderness with thirst, Elisha, the son of Shaphat, commands a minstrel to be brought to him: "And it came to pass, when the minstrel played, that the hand of the Lord came upon him. And he said, Thus saith the Lord," &c.

David.

According to Eusebius, David whithersoever he went carried his harp with him, to console him in his affliction, and to sing the praises of God. In this writer's preface to the Psalms he asserts that David, as head of the Prophets, was generally in the tabernacle with his lyre, with the other prophets and singers, and that each of them prophesied and sung his canticle as inspiration excited him. It will occur to every one that among the Hebrews Music was employed to relieve insanity. When Saul was afflicted he sent Messengers to Jesse to send his son, saying, "Let David, I pray thee, stand before me, for he hath found favour in my sight. And it came to pass, when the evil spirit from God was upon Saul, that David took a harp, and played with his hand: so Saul was refreshed, and was well, and the evil spirit departed from him." Burney, in reference to the circumstance of David being met, in returning from the field of battle after his victory over Goliath, by the women of all the cities of Israel " singing and dancing with tabrets, with joy, and with instruments of music," remarks on the passage, " and the women answered one another as they played, and said," &c., that this is an indubitable proof of a chant in dialogue, or for two choirs, being in early use, and that it probably gave rise to the manner of chanting the Psalms in the Cathedral Service. Women, it appears, were allowed the privilege of singing in the public ceremonies, and in 1 *Chronicles*, ch. xxv. ver. 5, in enumerating the Musical establishments for Religious purposes, we find that " God gave to Heman fourteen sons and *three daughters*. And *all these* were under the hands of their father for song in the house of the Lord, with cymbals, psalteries, and harps." Again, verse 7, " So the number of them, with their brethren, that were instructed in the songs of the Lord, even all that were cunning, was two hundred fourscore and eight."

The reign of David may be considered the Augustan Age, if it may be so termed, of Music among the Jews. He himself appears to have been an enthusiastic performer, and in the eyes of his Queen, Michal, to have so far outstepped the bounds of decency in dancing and playing before the ark, that she came out to meet him with the following ironical reproach. " How glorious was the King of Israel to-day, who uncovered himself to-day in the eyes of the handmaids of his servants, as one of the vain fellows shamelessly uncovereth himself!" In the same chapter, 2 *Samuel*, ch. vi. ver. 5, we have the following curious notice of the materials of which some of the Jewish instruments at that time were composed: " And David, and all the house of Israel, played before the Lord on all manner of instruments *made of fir wood*, even on harps, and on psalteries, and on timbrels, and on cornets, and on cymbals." The word ברושים, according to Celsius, means the cedar tree; if it be so, the elasticity of it is nearly as great as that of fir, and, therefore, it is as proper for Musical instruments. From this passage it is sufficiently manifest, that some of the instruments of this nation had sounding-boards or bellies of this material. Upon the quality of this wood the perfection of many instruments, indeed of all stringed instruments among the Moderns, depends; such are the harp, lute, guitar, piano-forte, and violin, whose bellies are constantly made of fir.

Instruments of fir wood.

Profession of Music hereditary.

As in Egypt professions were hereditary, so among the Hebrews the profession of Priest and Musician was hereditary in the Tribe of Levi. " And the sons of Aaron, the Priests, shall blow with the trumpets; and they shall be to you for an ordinance for ever throughout your generations." During the period of Moses, whether in peace or war, none but Priests blew the trumpets; so in Joshua's time, as well at the siege of Jericho, as on all other occasions, the blowing of trumpets was confined to the Priesthood; and on David's regulation of the Music of the nation so far as the service of Religion was concerned, not only the select establishment of singing men and singing women, but all the four thousand performers upon instruments, were of the families of Priests and Levites.

Josephus, book vii. chapter xii., says, that after David brought the nation to a state of profound tranquillity, he employed himself in composing odes and hymns of various measures in honour of God, some trimeters, and others pentameters. In another passage he says, the kinds of instruments he prepared, to the sound of which he taught the Levites to execute the praises of the Deity, were a ten-stringed harp touched with a quill, (*plectrum*,) a psaltery of twelve strings played upon with the fingers, besides large cymbals of brass.

Instruments.

It has been supposed, with apparent probability, that the spoils brought from Jerusalem, and among them Musical instruments, by the Emperor Titus, have been faithfully represented in the sculpture on his Arch at Rome. Among these are particularly the silver trumpets, and the horns supposed to represent the Shawms so often mentioned in Scripture, called in Hebrew *Keranim*, or Sacred Trumpets. The Arch of Titus is, however, known to have been erected after the death of the Emperor; and the instruments are not of uncommon form. The trumpets are long, straight tubes, and the horns such as frequently occur in ancient sculpture; representations of them may be seen in Blanchini, Bartholinus, Montfaucon, Padre Martini, and others, to which we refer the reader.

Musical characters.

Neither the ancient nor modern Jews appear to have had a set of Musical characters; so that the melodies used in their Religious ceremonies are mere matters of tradition, and subject to the alterations of those through whom they have been transmitted. Some learned men have considered the Hebrew vowel points in the nature of Musical characters, a conjecture which was confirmed to Dr. Burney by a learned Jew whom he consulted on the subject, who told him that the points still served two purposes;—" In reading the Prophets they merely mark accentuation, but in singing them, they regulate the melody, not only as to long and short, but high and low notes." Since the destruction of Jerusalem, Music, as well instrumental as vocal, has been banished from the Synagogue. It has been considered contrary to their law as delivered by one of the Prophets, to sing or rejoice until the coming of the Messiah; silence and repentance being prescribed till that period. The German Jews are not rigorously observant of this ordinance. Part-singing is allowed in the Synagogue by them, and in that at Prague an organ is to be heard. In Padre Martini's *Estro Poetico Armonico*, are some specimens of Hebrew Chants, sung in his time in different Synagogues in Europe; but so differently are they performed in different places, that if tradition has recorded them faithfully, it would be difficult to say to which antiquity can be assigned.

Greek Music.

Greek.

Of the ancient systems of Music that most completely described is Grecian, and the earliest Treatise that has reached us on the subject is by Aristoxenus, the disciple of Plato. The Greeks, however, were not the inventors of their own system, as Nicomachus has the honesty to confess. The invention of the lyre and of the Art of singing they attributed to the Egyptian Mercury, and their first Musical theory was imported into Greece by Pythagoras, who, after the manner of the Egyptian Priests, imparted it to his scholars as an inviolable secret. Jamblicus, in his life of Pythagoras, ch. xxiii., intimates that to the people it was known only in the shape of a symbolical language. Hence it did not survive the Sect by which it was cultivated. Though it has been declared by Jamblicus to be lost, modern

Musicians, and among them the Abbé Roussier and Rameau, have not despaired of unfolding its principles. The former, a person of great learning, had not sufficient Musical education to make his theory agree with experience, whilst the latter had not sufficient learning to suit his to the history which has been transmitted by ancient authors.

History.

But before attempting to give our readers the opinions which we entertain on the Music of the Grecians, it will be right to lay before them some general view of its history, which with them, as well as with other nations, is at its beginning mixed up with mythology and fable. Padre Martini, and after him Dr. Burney, have done little more than give us, relative to the early period, what they find in the Greek Classics, leaving the reader to separate Fable from History: in short, the latter has only abridged what he found in the former. In truth, the learned Martini has so exhausted the subject that little has been left for succeeding writers.

admus.

Cadmus, the son of Agenor, brought with him amongst the Phœnicians whom he introduced into Greece, a race who were called Curetes; these men were accompanied by the Arts and Sciences of Phœnicia, in which they were skilled. They spread in Phrygia, and were there named Corybantes; in Crete, where they were called Dactyli; they settled also at Rhodes, in Samothrace, and in other parts. Cadmus espoused in Samothrace Harmonia, sister of Jasius and Dardanus, who was so skilled in Music, that the Greeks honoured the Art itself with her name. Diodorus Siculus describes the ceremony of their nuptials, as having been attended by the Gods, and that Mercury was present with his lyre, Minerva with her flute, Electra, the mother of the bride, celebrated the rites of Cybele, dancing to the sound of drums and cymbals; Apollo was there also with his lyre, which was accompanied with flutes by the Muses. Diodorus lived too remotely from the event which he describes to give his account any credibility, were it even divested of fable; it is not, however, improbable that the marriage of Cadmus with Harmonia was marked by such Dramatic and Musical performances as the Age afforded.

e flute.

To Minerva is assigned the invention of the flute with several holes, apparently, and perhaps really, a much more ingenious invention than the flute of Pan, or Pan's pipes, which consisted of several tubes of different lengths. Hyginus relates that Minerva having excited the laughter of Juno and Venus whilst playing the flute, examined afterwards her reflected image in a fountain, and perceiving the grimace and contortions it produced in the face, threw her flute into the water, and thenceforward confined her Musical performances to the lyre. Lucian has amused himself with the quantity of employment which the Greeks gave to Mercury, among the rest of his feats was the invention of the seven-stringed lyre; this, however, must have been that of the Egyptian Mercury, as we have above mentioned. Apollo also seems Egyptian in his origin; his Musical contest with Pan is familiar to every one, and in the judgment of Midas we discover the fictitious revenge of some neglected Poet of Phrygia. Marsyas, another competitor with Apollo on the flute, did not escape without the loss of his skin. Fortunio Liceti* considers this tale allegorical, and thus explains it. Previously to the use of the lyre, the flute was the favourite instrument, and enriched all the best performers on it. As soon, however, as the people became familiar with the former, the latter sank into disuse, and as the coinage of that period, according to Pollux, was made of leather, Apollo may be said to have *fleeced* Marsyas. The Pythoness at Delphi pronounced her oracles in verse, and Plutarch says, that her voice was accompanied with the flute. In the suite of the five Priests attendant on the chief Pythoness, were a great number of Musicians, instrumental performers, choirs of young people of both sexes, who danced and sang at the feasts of Apollo to the sound of flutes and lyres.

The Muses.

In their origin the Muses were merely a troop of singers and Musicians in the service of Osiris, or the great Egyptian Bacchus, and under the direction of his son Orus. The Greeks converted them into the daughters of Jupiter and Mnemosyne. If it be contended that they were the daughters of Pierus, King of Thrace, it is answered, that the lady Musicians of Osiris had been previously known in Thrace under the name of Muses, and that the daughters of Pierus, who imitated them, became thus distinguished by the same appellation.

Bacchus.

Bacchus is too celebrated in Musical History to be neglected in this place. Diodorus says, that he was the inventor of theatrical representations, and of Schools of Music, in which those who distinguished themselves obtained an exemption from military service. Hence, he says, that at a later period these Companies of Musicians have enjoyed many privileges. Certain it appears that the Dithyrambi, from which dramatic pieces originated, were as ancient as the worship of Bacchus, and there is scarcely room for doubt that the celebration of his mysteries were the groundwork of the splendour and illusion of the Theatre. Thus in Rome, as well as Athens, those who appeared on the stage singing, dancing, and reciting poetry for the amusement of the audience, went by the name of the *Servants of Bacchus*. Pausanias mentions a place in Athens sacred to the singing Bacchus. Hence it may be concluded that Bacchus was considered by the Athenians the God of song as well as of wine. In short, in all the orgia, processions, triumphs, and solemnities instituted by the Ancients in honour of that God, Music was especially used. The number of bassi rilievi in which Musicians accompany him with the lyre and flute, and Fauns and Satyrs with tambourins, cymbals, and horns, sufficiently prove the fact.

Pan.

Among the inferior Divinities Pan seems to hold the first rank as a Musician. The Egyptians, however, it must be observed, classed Pan among the superior Divinities. He is said to be the inventor of the syrinx, or pipes, which bear his name. The story of his pursuit of the Nymph Syrinx, which led to the invention of the instrument, and bestowed on it its Classical name, is too well known to be repeated here. Lucian represents Pan as the companion and counsellor of Bacchus. Shepherd, Musician, dancer, hunter, and warrior, Bacchus appears never to have been happy without him. He it was who superintended Bacchanals: but above all things, his touch and breathing of the flute enchanted the jolly God. After Pan come the Satyrs, whom, says Pausanias, the Ancients called Sileni, doubtless in relation to Silenus, the preceptor of Bacchus; Silenus has also the reputation of having been a good Musician, and the inventor of several Musical instruments. He, like Marsyas, had the boldness to challenge Apollo, but unlike him came off with a whole skin.

The Sirens.

The Sirens, who were celebrated singers on the coast

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* *Hierog.* c. 109.

of Sicily, were placed amongst the terrestrial Divinities. Such was the enchantment produced by their singing, that the Argonautæ could escape them only by listening to the songs of Orpheus. They are said to have challenged, and to have been defeated in song by the Muses. Sicily was always notorious for its luxury and looseness of morals, and the whole story seems allegorically to relate that good sense and morality triumphed over immorality and dissipation.

Early celebrated Musicians.

Such was the state of Music in the primitive times of Greece under the government of the Gods and Demi-Gods; a period of simplicity and innocence in which all those who invented and taught mankind the useful Arts were deified after death, and regarded as the protectors of the Arts which they had introduced. We possess some little knowledge of the state of the Arts in these Heroic-Ages; but as it would be difficult to speak with certainty on the Music of so remote a time, we shall do little more than record a catalogue of its celebrated Musicians, separating as much as possible their History from Fable and Allegory. All the principal early Musicians, Amphion, Chiron, Orpheus, and Linus, were equally Poets and real benefactors of mankind. On this subject the laborious and learned compilations of Fabricius and Burrette may be consulted by those who desire to know pretty nearly all that has been written on the subject; a very short abridgement will be sufficient in this place.

Amphion.

Amphion, the twin brother of Zethus, is the only Theban Musician whose name has reached us, his reputation, however, rests on but slender foundation. He had dethroned Laïus, father of the unfortunate Œdipus, and Homer merely says, that in order to secure his usurped crown, he built a wall round Thebes, having seven gates and fortified with strong towers. He mentions not a word of his miraculous skill in Music, nor of his having constructed these walls by his talent in striking the lyre. Pausanias, and after him Pliny, seem to think that his Musical reputation was gained by his alliance with the family of Tantalus, whose daughter Niobe he married. Both agree that he acquired the Art in Lydia, and that having brought it into Greece, he was esteemed the inventor of the Lydian mode.

Chiron.

Chiron, called by Plutarch the wise Centaur, was accounted the son of Saturn and Philyra. He was born in Thessaly among the Centaurs, that is, among those early Greeks who had the address to break and ride the horse. He was the inventor of Medicine, Botany, and Surgery. Dwelling in a cavern at the foot of Mount Pelion, his science and skill made it the most celebrated and frequented School in Greece. Xenophon furnishes an ample list of his pupils, to which Plutarch adds Hercules, who he says in the School of Chiron learned Music, Medicine, and Law. Diodorus, however, assigns the credit of this scholar to Linus; be this as it may, it indicates that ancient writers considered the qualification of Music necessary to their Heroes, nor could there be a greater reproach to a person in those olden times, than to say of him, *Nec fides didicit, nec natare.* But of all the pupils of the Centaur, none did him so much honour as Achilles. Apollodorus relates that a considerable portion of his time was occupied by Music, and that he employed it for the purpose of exciting him to great deeds, as well as to repress the impetuosity of his character. One of the paintings discovered at Herculaneum represents Chiron teaching his scholar the Lyre.

Linus.

After Chiron, Linus and Orpheus appear to have been the chief Poets and Musicians of Greece, but which was the master which the scholar of the other, we have now no means of deciding. The authorities preponderate in favour of the priority of Linus. Diodorus, indeed. asserts positively that Cadmus taught the Greeks the use of letters, and that Linus instructed them in Poetry and Music. In another passage, he says that it was Linus who added the string *Lichanos* to the lyre. Some of the Ancients give him Hercules as a pupil. The story goes, that he succeeded so ill with that scholar, who was dull and obstinate, as to be provoked to strike him, which so exasperated the hero, that he seized his master's instrument, and knocked out his brains with it.

Orpheus.

Of Orpheus, whether before or after Linus, it may be affirmed the name is as illustrious as any which appears in the Grecian History. During the Argonautic expedition, which he accompanied, his reputation was established, and by the aid of his Musical abilities he was not only useful in keeping up the spirits of his companions, but rendered impotent the charms of the Sirens as we have above mentioned. With Music it is said he united the sublime Sciences, and was the first of the Grecians who planted them in his native Country. According to Pausanias he was the imitator of none, for before him, says that author, there was no other performer except on the flute. We shall not here dwell on the wonders his lyre achieved; to all are known the stories of his power over Cerberus, the Furies, and the Gods of Tartarus, and the beautiful fable of his endeavours to restore to Earth a beloved wife. The lyre which possessed such magic power, which softened the cruelty of savage beasts, and made trees and rocks attentive, was but an instrument of seven strings, of which the first Mercury invented four, in succeeding times two had been added, the seventh, which completed the second tetrachord, was superadded by Orpheus himself.

Obloquitur numeris septem discrimina vocum. Virg.

One may perhaps attribute these miraculous effects on the rude people who listened to him to the novelty of the Art, to the beauty and imagery of the Poetry, and to the extreme sensibility of the hearers more than to the perfection of the instrument. The death of Orpheus appears to have been not less unhappy than that of Linus. The most likely account seems, that having excited the jealousy of the Thracian women by the power his talents exercised over their husbands, they lay in wait for him in the woods, and there murdered him, having previously hardened themselves by excess for the commission of the crime. Plutarch remarks, that in his time the Thracians were in the habit of reproaching their wives with this barbarity. Fable concludes this tragedy by dropping his lyre into the Hebrus, down which it was carried to the sea, borne on to Lesbos, and there deposited in the Temple of Apollo. Lucian states that this instrument was a considerable time afterwards purchased by Neanthus, son of the Tyrant Pythacus, who was silly enough to believe that he had only to touch it to induce the rocks and trees to follow him, instead of which the sounds he produced from it were so hideous, that the dogs of his neighbourhood seized him and tore him in pieces.

Homer's Musicians.

After the expedition of the Argonautæ, of which Orpheus in his youth shared the dangers, the most memorable epoch in the Grecian history is the siege of Troy, of which Homer is the only Historian as well as Poet. He has preserved the names of several Musid Instru- nts.

cians, and they are the only memorial we have of the Art in Greece, during the long period extending from the time of Orpheus to the celebration of the Olympic Games. The instruments mentioned by Homer in the *Iliad* and *Odyssey*, are the lyre, the flute, and the syrinx or pipes of Pan. The lyre is always called φόρμιγξ, κιθάρα, or χέλυς, Aristophanes being the earliest Greek Poet who calls it λυρα. The instruments above mentioned were from that period employed in sacrifices and religious ceremonies. Homer mentions the trumpet as used in war, but this instrument, though common in his time, was probably unknown to the Greeks at the siege of Troy. Music appears to have been inseparable from the banquets and public ceremonies which he describes, there are none in which Music and Poetry are not mentioned. He speaks of Music as used in private life, for he describes Achilles and Paris consoling themselves with the lyre; the first on the fatal affront which he avenged by withdrawing himself from the army, the latter for the disgrace he had incurred in flying from the field. Among the Musical Poets named in his Works occurs Teiresias, a name celebrated in Grecian History, who in recompense for the loss of his eyes was endowed with the gift of Prophecy. According to the ancient practice he united Music, Poetry, and Prophecy with the sacerdotal function: he was the person consulted by Ulysses in obedience to the command of Circe. Thamyris is by Homer called κιθαριστής, one who sang to the lyre. Plutarch, in his Dialogue on Music, says that he was born in Thrace, the Country of Orpheus, and that his voice, in sweetness and quality, surpassed those of all the Poets of his time. It appears that he had a contention with the Muses as to skill, and the punishment for his boldness was blindness, loss of voice, and of the power of touching the lyre, and Homer notices the story in his Catalogue of the ships, *Iliad*, book ii. v. 594. Diodorus says that Thamyris was the pupil of Linus; Suidas, however, maintains that he was eighth in order of the Epic Poets who preceded Homer. Clemens of Alexandria makes him the inventor of the Dorian mode, but this would seem to have been in use before his time, having been imported to Greece by the Egyptians. With Homer, Demodocus seems to have been in the highest esteem as a Poet and Musician. At the Palace of Alcinous he announces his arrival through the medium of a herald, and seats him on a splendid throne. In short, the VIIIth Book of the *Odyssey* is so filled with the praises of this personage, that some have thought the Poet was painting the picture of himself. The remaining Musician whom Homer has celebrated is Phemius. Eustathius supposes him to have been the particular friend of Homer, and his instructor. If so, the master will live longer by the eulogium of his pupil than by his own proper merits, which have not reached us. The singing of the Poetry, not less than the verses themselves, seem to have been improvvised, and to have resembled the effusions nearer our own time of the Celtic Bards and the Scalds of Iceland and Scandinavia. The Poets were strollers, but respect for their talents insured them a warm reception from the Palace to the lowest hut in which they sought an asylum.

iresias.

amyris.

nodocus.

mius.

nis.

Hyagnis and Olympus, celebrated in History, were before Homer's time. The former, a Phrygian by birth according to the Arundelian Marbles, flourished 1506 years before Christ. He was the inventor of the Phrygian flute and mode, of the airs or nomes which were sung in honour of the Mother of the Gods, of Bacchus, Pan, and the other Divinities of the Country. The latter is frequently mentioned by the Greek writers. Two great Musicians bore this name; the earliest, who was a native of Mysia, was the most celebrated, and was a pupil of Marsyas. He added to the power of Music by the introduction of the ancient enharmonic system. He is celebrated by Plato, Aristotle, and Plutarch for his Musical and Poetical talent, as a person whose melodies remained even to their several times. Burney has well observed, that Religion is the only medium by which Music can be perpetuated. And it may be presumed that the airs which were common in Temples at the time of Plutarch, were to him, in point of relative antiquity, what the Gregorian tones of the Roman Catholics are to them in the present day. Plato describes the Music of Olympus as animating; Aristotle as filling the soul with enthusiasm; Plutarch says, that for simplicity and effect no Music then in use surpassed it. He further mentions its powers over Alexander, and that to his talent for Music he joined that of Poetry. His elegies and plaintive airs accompanied by the flute, appear to have been so moving and pathetic, that Aristophanes, at the beginning of his Comedy of the *Knights*, in which he introduces two Generals, Demosthenes and Nicias, as valets complaining of their master, puts into their mouths the words, "Let us weep and lament, like two flutes playing an air of Olympus."

Olympus.

Thaletas.

After Hesiod and Homer, the next Poet and Musician was Thaletas of Crete. He superadded the accomplishments of Philosopher and Politician to his other talent, so that Lycurgus passed into Crete to avail himself of his advice in founding his Government. His Odes, according to Plutarch, enforced maxims of harmony and concord, to which the sweetness of his voice and melody gave additional force. Plato, Porpyhry, Athenæus, and the Scholiast on Pindar speak of his talents, and mention melodies of his composition. There was another Thaletas, also of Crete, who flourished long after the time of Lycurgus, reputed to have cured the Lacedæmonians of the Plague by his performance on the lyre, and whom Plutarch makes a contemporary of Solon.

Archilochus.

Archilochus is esteemed the inventor of dramatic melody of song, applied to declamation, with us called recitative. According to Plutarch he adapted his Music to his Iambic verses in two different ways. Some he recited with an accompaniment at the end of the passage; others with the voice as it proceeded and in the same melody. The latter method was in the end adopted by the Tragic Poets. If Plutarch may be considered a competent witness, none of the Poets of antiquity contributed so much as Archilochus to the progress of Poetry and Music. Herodotus makes him contemporary with Candaules and Gyges, Kings of Lydia, 724 A.C., but modern Chronologists assign him a later period. He was born at Paros, one of the Cyclades. We do not intend to bestow any observations on the strange events in the life of Archilochus, his Musical career is all that concerns us. Plutarch attributes to him the rhythmical arrangement of Iambic trimeters, the sudden transition from one rhythm to another of a different genus, and the method of accompaniment to them on the lyre. Melody was at that period strictly regulated by the measure of the verse, the varying structure of which necessarily required variety of melody. Heroic or hexameter verse seems exclusively to have been practised by the ancient Poets and Musicians; they were unacquainted with the method of passing from one rhythm to another which Lyric

Poetry required. If Archilochus, therefore, was the inventor of this mixture, he is entitled to be considered the inventor of Lyric Poetry, a species quite distinct from all Poetry that preceded him. He is generally reckoned among the first conquerors of the Pythian Games. His Hymn in honour of Hercules obtained the applause of all Greece; on singing it at the Olympic Games, he received the crown; and such was the estimation in which it was held, that it was the practice to sing it thereafter in honour of those successful competitors who were not fortunate enough to have any Poet to write and compose for them on the occasion.

Tyrtæus.

Tyrtæus, the Athenian General, was a Musician, and History has recorded him as celebrated for the composition no less than the execution of his airs and military melodies. Notwithstanding the austerity of their manners, the Lacedæmonians acknowledged the power of Music so far as to call in Tyrtæus to their aid, and their victories are attributed to his Musical exertions at the head of their army. They rewarded him with the rights of citizenship, and to the latest period of the Republic were accustomed to use in war the Music which he had introduced among them.

Terpander.

Terpander, whose date and birthplace are unsettled, was, according to the concurrent testimony of the Ancients, another celebrated Musician. The Arundelian marbles indicate his existence 671 A. C. Some have assigned to him the addition of three strings to the lyre, which previously possessed but four. Be that as it may, it seems that he was the first who introduced them to the Lacedæmonians, and thus gave great offence; they were, one would suppose, little better than Savages, for through the Ephori, they fined him for the innovation. Plutarch, who mentions this circumstance in his Dialogue on Music, says, that Terpander quelled a disturbance among this people by the persuasive sounds of his voice and lyre. The circumstances appear to contradict each other, but they may be reconciled by the supposition of his having, after a time, overcome the prejudices of so rude a nation. Terpander was not less celebrated for his instrumental talent on the flute and lyre than for his compositions, inasmuch as from the marbles before cited, as well as from the testimony of Athenœus, it appears that he obtained the first Musical prize at the Carnian games instituted at Sparta to deprecate the anger of Apollo for the murder of Carnus, one of his Priests, which the Dorians had perpetrated. In short, if we may rely on Plutarch, no other testimony in favour of Terpander is required than the simple statement that his name was on the records of the Pythian Games as the successful competitor in four successive contests.

Grecian Games.

In the Grecian Games, Music occupied a considerable portion of the ceremonies: independent of the combats being accompanied by the sound of instruments, and of the competition in dramatic exhibitions, wherein the dialogue was sung and accompanied by the orchestra, there were especial prizes for Music. We will glance at these Games as connected with the Science.

Olympic Games.

For a considerable time Music was subordinate to the other exercises at the Olympic Games. It was not until the XCVIIth Olympiad, that a prize was awarded to the best player on the trumpet, an instrument which, till then used only as a signal for troops, had been brought to a state of considerable perfection. Burney observes, that it was probably used in accompanying the voice, and equally so that it was the first among the ancient instruments upon which a solo was performed. Prizes were adjudged in these Games also to the flute and the lyre, and used to be contested for down to the abolition of the Games themselves.

Pythian Games.

The Pythian Games, instituted to record the victory of Apollo over the serpent Python, were, according to Pausanias, in their origin merely Poetical and Lyrical competitions. The prize was adjudged to the best composer and singer of a Hymn in praise of Apollo. Eleutherus is recorded among the earliest victors as having been successful for the prize by the power and sweetness of his voice, although the Hymn he sang was the composition of another. Hesiod is said to have been unqualified to compete, because he could not accompany himself on the lyre. Homer also was told by the Oracle that he was an unqualified person, because his blindness and infirmities disabled him in too great a degree from singing and playing on the lyre together. After the Crissæan, or Sacred war, the Games were celebrated in the second year of each Olympiad. At this period, 591 years before Christ, two other prizes were added to those already named, one for those who sang the best to a flute accompaniment, the other for those who without singing played on the instrument with most feeling and taste. Here begins the separation of Music from Poetry, till then indissolubly united. Sacadas of Argos is handed down as the first victor on the flute alone. In the VIIIth Pythiad, 559 years before Christ, a crown was decreed to the best performer on a stringed instrument without the voice. The prize in all the Pythic contests was a crown or wreath of laurel, in memory of the plant into which Daphne had been transformed; at a later period it was interspersed with the apple, a fruit consecrated to Apollo. Strabo, in speaking of the different sorts of contests established in the Pythian Games, mentions a peculiar species of composition sung in the manner of a Hymn to the honour of Apollo, and accompanied by instruments. It was called the Pythian Nome, or Cantata, (Νόμος Πυθικός,) and was a very long piece consisting of five parts, all containing allusions to the victory of the God over the serpent. The first part, called the prelude, described the preparation for the combat; the second, the onset, or beginning of the contest; the third, the heat of battle; the fourth, the song of victory, or the insults of Apollo over Python, consisting of iambics and dactyls; and the fifth and last, the hissing of the dying monster. Pausanias relates, that this cantata or nome was invented by Sacadas, a Poet as well as Musician, and performed first by him at Delphi. Of this Sacadas, we have the testimony of Pausanias and Plutarch, that Pindar thought highly of him, and, in some Works now lost, paid a tribute of praise to his Lyric and Elegiac Poems. The following are the principal Musical Poets who obtained celebrity at the Pythian Games. Alcman, a native of Sardis, flourished 670 years before Christ. It is said that in his youth he was a slave at Sparta, but that his good disposition and genius acquired for him his freedom as well as a distinguished rank among the Lyric Poets. He played with consummate art on the lyre, and excelled in singing his Poetry to a flute accompaniment, in the composition of Music for dancing, and, above all, in strains of love and gallantry. He was one of those great Musicians whom the Lacedæmonians called to their assistance on state occasions, to animate the troops, and guide them in their evolutions. Alcæus, born at Mytilene, flourished, according to the Chronicle of Eusebius, in the XLIVth

Sacadas.

Alcman.

Alcæus.

Olympiad, or 604 years before the Christian Era. He abandoned military glory for that which he obtained in the service of the Muses, after having, like Archilochus before him and Horace after him, fled from a field of battle in which he lost his buckler and his honour. He excelled equally in Poetry and Music, and composed Odes, Hymns, and Epigrams. His Poetry, sometimes threatening tyrants, sometimes in the plaintive strain of a lover, was, according to Quinctilian, chaste, concise, magnificent, and sententious, and approaching so near the standard of Homer, that Horace has bestowed on him a golden plectrum.

> *Et te sonantem plenius aureo,*
> *Alcæe plectro.*

pho

Alcæus was contemporary and native of the same Country with Sappho. That Poetess, whose adventures, and the fragments of whose Poetry are too well known to require particular mention here, is recorded by Aristoxenus and Plutarch to have been the inventress of a new Musical system, called the Mixolydian Mode. The Lydian was the highest in respect of scale of the five original Modes, and its lowest note, or added (προσλαμβανόμενος) string, seems to have corresponded with our F ♯ on the fourth line in the bass or F clef. The Mixolydian, invented by Sappho, is usually considered to have been a half note higher. This Mode afterwards received the addition of a minor third above, taking thence the name of the Hypermixolydian, and thence the fourth above, with the appellation of the Hyperlydian Mode. Plato, in the IIId Book of his *Republic*, complains of the extent of the scale used, and wishes Music to be restrained within more moderate limits than those employed by Sappho. But we shall hereafter have to speak a little more at large on this subject, when we consider the origin of the Ecclesiastical tones.

nner-
s.

Towards the beginning of the VIth Century before Christ, Mimnermus, according to Plutarch, became celebrated for a *nome* on the flute, called Cradias, at that time in common use at Athens at the procession of the expiatory victims. This Mimnermus was a Lyric Poet and Musician of Smyrna, and contemporary with Solon. To him Athenæus attributes the invention of the pentameter verse, and his Elegies were in so great esteem among the Ancients that Horace prefers them to those of Callimachus. But few fragments of them remain.

ichorus.

Next in chronological order is Stesichorus, a Sicilian, and native of Himera. His original name, Tisias, was abandoned in consequence of the alterations introduced in the dithyrambic chorus. Simonides flourished about the same period; he was born at Ceos, one of the Cyclades, about 538 years before our era, and died at the advanced age of ninety. Pliny attributes to him the addition of an eighth string to the lyre, but the Learned are not agreed on this subject.

nides.

r.

Pindar, whom to name is to secure attention, was born at Thebes, in Bœotia, about 520 years before Christ. His father, a Professor of the flute, gave him his first Musical instruction. He was afterwards placed under the care of Myrtis, a woman distinguished for her Lyric Poetry. Under a course of instruction with her, he found Corinna, to whom, Plutarch says, the young Pindar was more indebted for his progress than to their joint mistress herself. He was afterwards the pupil of Simonides, then well stricken in years. Pindar distinguished himself in all his contests in Music and Poetry, then so common in Greece. He competed with Myrtis and Corinna, of whom the former may be said to have been his Musical mother, and the latter his sister in the same Art. The former he excelled, but the latter was five times successful against him. Pausanias hints that the personal attractions of Corinna, of whose Works no fragment is known to us, had some influence on the arbitrators. His only pieces that have reached us are compositions in honour of the conquerors at the Olympic, Pythian, Nemæan, and Isthmian Games. He died when eighty-six years old, and his fellow-citizens erected in the Hippodrome at Thebes a monument to his memory, which existed in the time of Pausanias. Alexander, when he took that city, respected his house and descendants. The Lacedæmonians paid similar tokens of respect when they ravaged Bœotia and burned its Capital; and in so great esteem did his memory continue, that Plutarch says, in his time the best parts of the sacred victims were reserved for the use of his descendants.

High esteem for Music in Greece.

Music had now arrived at an extraordinary pitch of perfection. All the cities of Greece, not excepting Sparta itself, were led by its charms; and Plutarch informs us, in his *Life of* the Spartan *Lysander*, that the Musician Aristonoüs, six times a successful competitor as a Citharædist in the Pythian Games, flattered that Chief by telling him that if he ever gained another victory, he would be content to be proclaimed his disciple and servant. This compliment was paid after Lysander had taken the city of Athens, beaten down her walls, and burned the fleet in her harbour *to the sound of flutes*, in the XCIVth Olympiad, 404 years before Christ.

We receive from ancient authors incontestable proofs of Musical contests in the Games down to the epoch of their abolition, after the establishment of the Christian Religion. It is sufficient to mention the laurel won by Nero at the Pythian Games, sixty-six years after the Christian Era, and the two Pythian victories, amongst a number of others recorded in the Arundelian Marbles gained by C. Ant. Septimius Publius, a flute-player in the time of the Emperor Septimius Severus. We will conclude by observing that the Pythian Games in honour of Apollo were celebrated at Miletus in Ionia, at Magnesia, Sida, Perga, and Thessalonica, as well as at Delphi, and that in each of these places Music and Poetry were the subjects of principal contest.

Nemæan Games.

The Nemæan Games received their name from Nemæa, a village of Arcadia, and were of so great antiquity that the Ancients themselves are not agreed upon their origin. According to some, they were instituted in honour of Archemorus by the Seven Chiefs against Thebes; others say they were founded by Hercules to compliment Jupiter after the victory over the Nemæan Lion. The display was very similar to that in the Olympic Games, and certain it is, on the authority of Plutarch, that Music was one of the Arts in highest esteem. In his *Life of Philopœmen* he records, that he entered the Theatre, after the celebrated victory of Mantinæa, during the Nemæan Games, whilst they were contending for the Musical Prize. The Musician Pylades, of Megalopolis, began to sing to the lyre an air composed by Timotheus, the words of which appeared so applicable to Philopœmen, that all eyes were fixed on him, and the song was interrupted by public applause and acclamation.

Pylades.

Timotheus.

Timotheus, another celebrated Poetic Musician, was born at Miletus, 446 years before Christ. He excelled not only in lyrics and dithyrambics, but also in the art of playing on the lyre. According to Pausanias, he added four strings to the seven already in use on that instrument, though Suidas says, that even before his time it had nine, and that he added only the tenth and eleventh. Be this as it may, it appears his improvements gave great offence at Sparta, and he was ordered to detach from his instruments the additional strings and revert to the original number. He was, moreover, banished the city for his refinements. We have mentioned in a former page a similar treatment of Terpander by these unmusical Spartans. The Lacedæmonians appear, however, to have admitted the use of the enharmonic genus on account of its simplicity, but to have disapproved of the chromatic as too difficult and refined: a fact affording proof of the existence of two species among them, whereof the more ancient appears to have been remarkable for its simplicity and dignity. Timotheus died at Macedon, at the age of ninety-two years, and before the birth of Alexander the Great. He is not to be confounded with the celebrated flute-player, who by his Art raised the passions of that Monarch, and as easily allayed them. He was a native of Thebes.

Isthmian Games.

The Isthmian Games received their name from the Isthmus of Corinth whereon they were celebrated. In these, as in the former, Music and Poetry bore a principal part. But in respect to the History of the Art which is the subject of this Essay, they present little that is remarkable. We cannot, however, close the History of Greek Music without some allusion to the celebrated Panathenaic Games of Athens. There were two festivals bearing that name, and of so great antiquity as to be carried back to the time of Orpheus. The greater Panathenæa were celebrated every five years, the lesser every three years, though some authors say the latter were solemnized yearly. Among the prizes distributed were especially those for Poetry and Music. The tale that these Games were originally founded by Pericles, however his taste and love for the Arts might justify such a conjecture, is sufficiently contradicted by the testimony of Plutarch, who examined the registers of their celebration, and carried them back to a much more remote period. In these Games, players on the flute and lyre exercised their talents on subjects selected by the Directors of the ceremonies, and whilst Athens enjoyed freedom and independence, the names of Harmodius and Aristogiton wanted not a Poet or Musician. The flute, always a favourite instrument at Athens, probably because its invention was attributed to Minerva, attracted cultivation from the prizes assigned to performers on it at these Games. Although Aristotle speaks of the flute at its earliest introduction as an unworthy instrument, and of little account, yet after the invasion and defeat of the Persians, its use had become so universal, that unacquaintance with its use was a reproach to a well-bred person. The Athenians Callias and Critias, Archytas of Tarentum, Phylolaus and Epaminondas, were excellent flute-players. In short, Music was in so great esteem at Athens in the time of Pericles and Socrates, that Plato, as well as Plutarch, have thought it necessary to leave a record of the persons from whom those two celebrated personages received their instructions in that Art.

Panathenæa.

The Flute.

Damon.

Damon the Athenian was the instructor in question. Socrates calls him his friend, a distinction sufficiently flattering to his memory. He was the pupil of Agathocles, who, besides the qualities which, in Plato's opinion, peculiarly fitted him for the instruction of youth, cultivated also that branch of the Science which more particularly related to time and measure, and thus attained a more than ordinary reputation in the eyes of that Philosopher. Pericles, who was a patron as well as an enlightened judge of the Arts, was desirous to enlist the Muses in all public amusements. He not only regulated the mode and augmented the number of the Musical and Poetical contests, but he also built the Odeon, a building appropriated to the daily practice of Poetry and Music, previous to their production at the Theatre. To Pericles the Athenians were also indebted for the settlement amongst them of Antigenides, a highly celebrated performer on the flute, and one of the best Musicians amongst the Ancients. According to Suidas, he was a native of Thebes in Bœotia, whose inhabitants were famous as performers on that instrument. He was a pupil of Philoxenus, of the Island of Cythera, whose Lyric Poems are entirely lost. The pupil, in his youth, went about with the master, and accompanied on the flute the airs which the latter composed to his Poems. Reared in such a school, it is not surprising that the former, in his turn, met with encouragement from the highest classes, and he accordingly was intrusted with the education of Alcibiades, the cousin of Pericles. Aulus Gellius tells us, that Alcibiades, however, was disgusted with the instrument, as Minerva had been before him, and by discarding it brought it into disesteem among the young nobility of Athens.

Pericles.

Antigenides.

According to Athenæus, Antigenides was the Musician who played the flute at the nuptials of Iphicrates, the Athenian General, who married the daughter of Cotys, King of Thrace. Plutarch assigns to him the honour of having stimulated Alexander by his Music, but the reputation seems more likely to have belonged to Timotheus. Notwithstanding his success and celebrity, this great Musician looked upon public patronage as a very precarious possession, and never allowed himself to be puffed up by the applause of the multitude. He impressed similar sentiments on his pupils, and with the view of consoling one of great merit, who had received but little encouragement from applause, he encouraged him by saying, "The next time you play shall be to myself and the Muses." He introduced several improvements in the instrument by increasing the number of holes, and thereby extending its compass. Theophrastus, in his *History of Plants*, informs us of the particular season at which Antigenides cut the reeds for his flute, in order to procure a quality of tone suitable to the refinements which he introduced in the Art; and Pliny has translated the passage. (xvi. 36.) Antigenides appears to have had a portion of the coxcomb about him, for he extended his regulations beyond the instrument, to the dress of the performer. For instance, it appears that he was the first who appeared in public in Milesian slippers and a robe of saffron colour. Relative to him, Plutarch records a joke of Epaminondas, who, on being informed that the Athenians had sent troops into the Peloponnesus with new arms, inquired, "Whether Antigenides had been disturbed when he saw new flutes in the hands of Tellis?"

Dorion.

Dorion was the contemporary and rival of this master. Plutarch mentions him as having made many changes in the Music of his time, and as being at the head of a party which opposed another under Antigenides. Though greatly extolled by Athenæus, there is ground for believing that his good companionship did more for his fame than his skill as a Musician. A circumstance mentioned by Plutarch in his *Life of Isocrates*, will give our readers some notion of the abundance of Flute-Music at Athens. The Orator (Isocrates) was the son of Theodorus, a manufacturer of flutes, who acquired sufficient fortune by his business not only to bestow on his children very superior educations, but to be able to bear one of the greatest burthens to which an Athenian citizen was liable, namely, the support of a choir for his Tribe or Ward on all public occasions. The wealth, however, of Theodorus does not appear so extraordinary, when it is known that the great sum of three talents, equal to upwards of £500 sterling, was given for a flute by Ismenias at Corinth. Now, though this Ismenias, of whom Pliny and Plutarch mention some ridiculous tales, may have been a silly fellow, yet even allowing for extravagance, it shows that a good instrument found a ready purchaser and a large price. Montfaucon may be consulted to prove, from inscriptions on antique marbles, the great estimation in which the instrument was held. At Athens the flute-players attached to the sacrifices were nominated at the same time with the State Officers; they were almost as much esteemed as the Priests themselves, having a share of the flesh of the victims, and the proverb of Αὐλητοῦ βίον ζῆν was applied to a man who lived chiefly at the tables of others.

onas.

From the list of celebrated flute-players the name of Clonas, according to Plutarch, deserves to be drawn forth; he was a contemporary of Terpander, and the first who composed *nomes* or airs for the flute. Polymnestes, a native of Colophon in Ionia, composed as well for the flute as he played on the lyre, which was not common among the Ancients. He is reputed to have been the inventor of the Hypolydian Mode, a semitone below the Dorian, and the lowest of the five original Modes; it was, perhaps, the first extension downwards of the scale as the Mixolydian was upwards. Telephanes of Samos was distinguished in the time of Philip of Macedon, not only by his talent on the flute, but by being honoured with the friendship of Demosthenes. In the time of Pausanias, a monument still remained to his memory between Megara and Corinth erected by Cleopatra, Philip's sister. The practice of the flute extended to the fair sex; and among the celebrated female performers must be recorded the name of Lamia, whose proficiency on it, added to her wit and beauty, caused her to be considered a prodigy. Plutarch, Athenæus, and others, speak of the honours she received throughout Greece. She is mentioned by Plutarch in his *Life of Demetrius*, as having so wrought upon that Prince in favour of the Athenians, that they rendered her divine honours, and dedicated a Temple to her under the name of Venus Lamia.

lymnes-
t.

lephanes.

nale per-
ners on
flute.
nia.

ension
e scales.

Whilst Instrumental Music was confined to the accompaniment of Poetry, its limits were restricted within narrow bounds; but in proportion as the Musician divested himself of the laws of metre and prosody, the strings of the lyre and the holes of the flute increased in number. These additions brought with them new, varied, and complicated movements and intervals, and their consequent extraordinary modulation. This change, whereof Aristotle bitterly complained, was after his time carried to excess. The Philosophers raised their voices against the innovations, which they considered detrimental to the morals of the people; who, never disposed to sacrifice the pleasures of sense to those of intellect, listened to the novelties with rapture, and bestowed the utmost patronage upon the composers; so that Music, which had at first been the humble companion of Poetry, finally became its sovereign mistress. Plato, Aristoxenus, and Plutarch complain not less than Aristotle, of the corruption and decay of Music among the Greeks. The former considered the Art as fitted only for Religious purposes; hence he condemned its use in public feasts, in the Theatres and as a domestic amusement. The complaint of Aristoxenus, as he was a sound Musician, would be entitled to some consideration, if it were not probable that the success of his rivals had some tendency to bias his judgment. Plutarch also, himself a Priest of Apollo, must be read on this point with caution. Athenæus, a more independent person, observes, that notwithstanding all that had been written on the subject, the Art in Greece in his time owed its principal attractions to the Theatre. Grecian Music, like the other Arts, had its infancy, maturity, and decay. After the conquest of Greece, neither her actions nor her works of Art indicated her former greatness; yet Music continued to be cultivated under the Roman Emperors. It has always been one of the solaces of the Greeks even under the dominion of the Turks; but unless their Music at present be essentially different from what it was in the periods whereof we have been treating, nothing could have been more barbarous or less likely to please a modern ear, than ancient Greek Music. But notwithstanding all that the Learned have written on the subject, so much is the Art an object of sense, and so momentary is its influence, that however clearly the technicalities may be explained, the effects on the organ will remain in profound obscurity. Who would be able to understand the full powers of Beethoven or Mozart a century hence, should modern Instrumental Music fall into decay in the interim from want of competent performers?

Decline of
Grecian
Music.

Roman Music.

Roman
Music.
Origin.

Although the Romans were chiefly indebted to the Greeks for their Arts and Sciences, yet (since no nation, however uncivilized, has ever yet been known to be entirely without knowledge of some rude sort of Music) it appears that at a very remote period they were in some measure acquainted with the Art, perhaps formed on Etruscan models, for Religion and War. Their connections with Etruria were long antecedent to those with Greece; yet as it must be remembered that the Arts of the former Country were very similar to those of the latter, it might be that the Music of which we speak came from Greece through Etruria. Strabo and Livy expressly state that the Roman public Music was imported from the Etruscans. More than one author has seriously found an early origin for the power of the modern *Improvvisatori* of Italy in a passage of Dionysius Halicarnassensis, (lib. ii.) which describes the first Roman Triumph, (that of Romulus over the Cænicenses,) when the army in three divisions sang in honour of the Gods, and moreover celebrated the exploits of their General by extempore verses. Burney, with much solemnity, says on the passage, "This account affords a very venerable origin to the *Improvvisatori* of Italy, as the event happened in the fourth year of Rome, 749 years before Christ and fourth year of the seventh Olympiad." Dionysius remarks, that the Roman Prætors annually celebrated Games in honour of Cybele, according to the Roman and not the Grecian custom, that her statue was with great solemnity paraded round the city to the sound of cymbals, followed by performers on the flute playing airs in her honour. These are the only traces to be found in Ancient History of Music originally Roman, or at least of Music that does not appear to have been brought from Greece.

The Salii.

The Salii, instituted by Numa, danced and sang Hymns to the praise of the God of War. Armed whilst engaged in the dance, sometimes, says Dionysius, they moved together, sometimes by turns, and were accompanied in the dance by certain Hymns, according to the custom of the Country. Their appellation was derived from the violence of their action, *à saliendo*, and conveys therefore but a mean notion of the refinement of their Music. Servius Tullius, who divided the people into classes and centuries, directed that two centuries should entirely consist of trumpeters, horn-players, and those whose duty it should be to sound the charge. This was 600 years before Christ, and proves the early importance of military Music among the Romans. By the laws of the Twelve Tables, 150 years afterwards, the master of the ceremonies at funerals is to provide ten flute-players, and the praises *honoratorum virorum* are to be proclaimed, accompanied with mournful songs to the sound of the flute.

Epithalamia.

The Hymeneal Songs, which were in after-times changed and refined down to Epithalamia, were, as we learn from Servius, Macrobius, and Horace, in their origin indecent and obscene compositions, called Fescennine verses, which young people sang before the apartments of the new-married couple. Livy (vii. 2.) gives us a tolerable sketch of the History of the Roman Drama, from which, as in Greece, Music was inseparable. The account is sufficiently interesting to deserve extraction. "This year (364 B. C.) the Plague continued to rage, and in that succeeding, under the Consulate of C. Sulpicius Peticus and C. Licinius Stolo. During this period the most memorable circumstance was the celebration of a public feast called the *Lectisternium*, to obtain the favour of the Gods, being the third of the kind that had been celebrated since the building of the city. The authorities, however, finding that the violence of the pestilence neither abated through human care nor divine assistance, and being moreover superstitious to a high degree, among other modes tried to appease the incensed Deities, are said to have instituted the *Ludi Scenici*, amusements entirely new to a warlike people, who previously to that period had none but those of the Circus. These dramatical exhibitions were, like the beginnings of most other things, inconsiderable, and borrowed from foreigners; inasmuch as actors were brought from Etruria, who, without verses or action expressive of them, danced not ungracefully in the Tuscan fashion to the flute. The Roman youth in process of time imitated these dancers, mingling raillery with their rude verses, and gestures correspondent with the import of the words. These Plays thus received at Rome were improved and refined by repeated performances. The Roman actors acquired the name of *Histriones* from the Tuscan word *hister*, signifying a stage-player. The dialogue no longer continued to consist of unpremeditated and coarse jests in rude verses like those of the *Fescennini*, but of Satires accompanied by Music set for the flute, and recited with proper gesticulation. Some years afterwards Livius Andronicus first ventured to abandon Satires, and wrote Plays with a regularly connected plot. Satires, which had afforded subjects of coarse mirth and laughter to the people, were thus reduced to form, and Acting gradually became an Art. The Roman youth now left it in the hands of Players by profession, and, as formerly, farces were acted at the end of their regular pieces. These Dramas soon after obtained the name of *Exodia*, and were usually interwoven with the Atellane Comedies; pieces originally borrowed from the Osci, and always performed by the Roman youth, who did not allow them to be disgraced by professed actors. Hence it was a rule that those who performed in such pieces were not to be disgraced from their Tribe, but were to serve in the army as though they had never appeared on the stage."

Lectisternium.

Dramatic Pieces.

The circumstances under which these pieces were first represented show that the Theatrical Games among the Romans were of Religious institution, as they were among the ancient Greeks, and the importance of Music in Religious ceremonies is confirmed by another curious passage in Livy, (ix. 30.) where he relates the effects of the resentment of the Roman Musicians, who commonly played during the sacrifices, and who imagining that they were affronted, withdrew in a body from the city to Tibur. The Tiburtines entreated them to return, but the Musicians were inflexible, and stratagem was obliged to be used. Different persons besought them on a certain festival day to come and assist at the celebration. Being plied with wine beyond moderation, they fell asleep and became insensible, and were then placed on cars, and carried back to Rome. There they passed the rest of the night in a public part of the city. In the morning, when the fumes of the wine began to be dissipated, they were surrounded by the people, who appeased them by granting them the privilege of parading the city three days every year in the costume of their profession, with liberty to play on their instruments, and to give themselves up to every species of licence and excess. This anecdote proves the importance attached to Music in Religious rites, not less than the licentious dispositions of the Professors of the Art. Music was long confined to sacred use, and it was not till after the defeat of Antiochus the Great, King of Syria, that Musicians (*Psaltriæ*) were introduced at Rome to play in the Asiatic fashion at festivals and private banquets.

In respect to Etruscan Music, the published collections of the antiquities of Etruria sufficiently show that its ancient inhabitants must have been much attached to the Art. All the different sorts of Musical instruments which are found on Grecian sculptures are equally to be seen on Etruscan vases. If the Romans lacked genius in the invention of the Arts, they certainly had the good taste to admire and imitate those of the Greeks after conquering them. Like them they had Public Games, combats of *athletæ* and Chariot-races. Their Generals, when honoured with a Triumph, entertained the people with Spectacles, in which Music had a conspicuous share, especially on the last day. Cæsar gave the first *Naumachia* on the Lake Fucinus, near Rome, which is said to have been attended by ten thousand Musicians of both sexes, who sang and played on instruments; and at his funeral, the Musicians in attendance threw their instruments on the pile. Music declined under Augustus, who probably cared little about it. In his time clapping of hands and whistling was introduced at the Spectacles. He had, however, a good voice, and at a late period of his life he employed a Musician to teach him to regulate it so that it might be more advantageously used in his Speeches. At his death, the Senate and principal citizens received his body without the gates of the city, and

Under Tiberius.

conducted it to its sepulture singing mournful verses to his memory. After his decease Tiberius banished the Comedians and Musicians; Caligula recalled them; Claudius also encouraged them, but he preferred Gladiatorial fights to Theatrical exhibitions.

Nero.

Nero restored Music to all its former splendour, and cultivated it himself like a Professor; it has been affirmed that he poisoned Brittanicus merely because he had a more agreeable voice than his own. He passed the greatest portion of his time in receiving lessons from Torpus, the most skilful harpist and lyrist of his time, whom he lodged in his palace. His first appearance on the Theatre was at Naples, which city he entered dressed as Apollo, and attended by the best Musicians of his time and by a crowd of his officers in a thousand chariots. Scarcely did he tread the stage before an earthquake shook the Theatre, but with the greatest coolness and presence of mind he continued his song, notwithstanding a considerable portion of the audience fled with precipitation. So delighted was he with the applause received at Naples, that he preferred it to every other city. A crowd of Musicians from all parts soon arrived to judge for themselves of the talent of the Emperor. Of these he retained five thousand in his service, and appointed for them a distinguishing uniform and a suitable salary. At his return from Naples the people were so impatient to see him on the stage, that he stopped a day there at their earnest supplication, to indulge them with the sound of his celestial voice. He was received with great applause, and thereafter made no difficulty of playing at Rome, and even of receiving payment for his performance, esteeming every thing at a high rate which was obtained through Music. Encouraged by this success he proceeded to Greece to contend for the prize at the Olympic Games, which he obtained by bribing his rivals and judges. In his journey afterwards through Greece, he every where challenged the most skilful Musicians, and, as may be supposed, always came off conqueror, as well on the lyre and harp as in singing. At his return from Greece to Naples, he entered that city, and afterwards Antium and Rome, by breaches in the walls of each, as a conqueror at the Olympic Games, bearing with him in triumph as the spoils of an enemy, eight hundred prizes which he had extorted in his Musical contests. By the wheels of the same chariot at which Kings conquered by the Romans had walked, and with similar pomp and solemnity, now trod through the streets of Rome Diodorus, a celebrated Grecian lyrist, with other distinguished Musicians. One hardly knows which most to wonder at, the vanity of Nero, who believed himself in possession of the first-rate talents, superior to those of the Professors; or the fulsome adulation of the artists in publicly acknowledging their defeat by the Emperor. The care which Nero bestowed on his voice, as related by Historians, is interesting as throwing some light on the practice of the singers of antiquity. At night he lay on his back, with a thin plate of lead on his stomach. He cleared the body by clysters and emetics, and abstained from all sorts of fruit and dishes likely to injure the voice. Suetonius says, that the best way of acquiring his good graces was to praise his voice, which was weak and thick, to affect to be in transports when he sang, and to appear sorrowful if, like most singers, he left off through caprice. Such was his passion for the applause of the multitude, that he appeared almost daily on the Stage; and Vespasian, who was afterwards Emperor, gave him great offence by trying on one occasion to escape from the private Theatre in his Palace while he was singing.

Hadrian.

Commodus.

Decline of Roman Music.

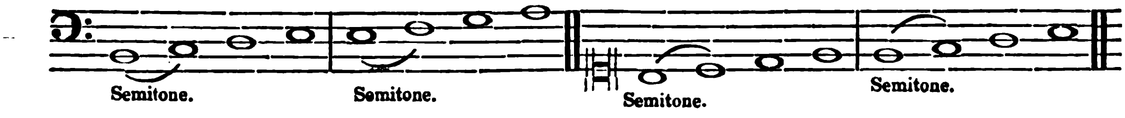
The successors of Nero encouraged public Games and Musical and Dramatic representations in all the great cities of the Empire. Hadrian, who was educated at Athens, was much attached to the Arts and habits of Greece. He established new Games; and Antoninus, who followed him in power, instituted others also in his honour, which were celebrated at Puzzuoli in the second year of every Olympiad. Commodus, a monster almost as cruel as Nero, was like him delighted also to appear on the Stage; but it seems that he was more of a dancer than an actor or singer, and that his chief pleasure was in presenting himself as a Gladiator. The fall of the Empire drew with it that of the Arts, and Music disappeared with the rest of them, till the period at which it revived in modern Italy, to spread thence throughout Europe, and to surpass not only that which had existed in ancient Rome, but even that which the Greeks had never been able to teach their scholars and conquerors.

Modern System of Music.

Modern Music. Aristides.

Tetrachord.

Aristides Quintilianus, a writer on Music, who is supposed to have lived about the IId Century of the Christian Era, and whose three Books on Greek Music were printed by Meibomius among the *Antiquæ Musicæ Auctores*, though he treated the subject more like a moralist than a professional man, gives many curious particulars and opinions on the Art as practised in his days. He ultimately reduces his definition of Music, however, to the study of the voice and accompanying action. It is not necessary to enlarge upon his doctrine here, we shall merely state that he divides Music into the contemplative and the active; the first regarding its causes and principles, the last the application and employment of them. The word *harmony*, to which a strict meaning is attached by all modern writers, was by the Ancients understood as the arrangement of the sounds of the system; and it may be observed that Quintilianus certainly understood the division of the three genera with which we are acquainted, namely the diatonic, the chromatic, and the enharmonic; the diatonic embracing, in a space of two octaves and a half, the interval between the *la* below our bass clef and our *rè* on the fifth line of the soprano clef. This is the full extent of a man's voice, and contains eighteen strings or notes. These, as will be seen below, were divided, beginning at the second, into tetrachords, or combinations of four notes, each succeeding the other by the progression of one semitone and two tones.



It will immediately occur to the reader that any one of these notes might become that final in an air, by which many modes or keys would be obtained, each being superior or inferior, as the air might extend above the key note, or as the key note might occupy the centre. Each note was indicated by a particular mark, according to its mode and genus, and it is manifest that each genus must introduce a number of new notes also represented by different marks, varying as the mode, and thus forming an almost infinite vocabulary. As in the formation of these marks or signs analogy was not kept in view, nothing was more confused than the study of Music, and it was proportionably difficult. Music was subservient to Poetry, so far as rhythm and metre were concerned; and at the period whereof we are speaking, Musical composition was exclusively confined to vocal pieces, and no precept whatever occurs relative to the use of intervals in harmony; and we might, doubtless, conclude that the Ancients were unacquainted with that which we term HARMONY; even if we did not possess positive knowledge of the origin and progress of modern Harmonic Art, as will hereafter be seen.

Music of the early Christians.

In the assemblies of the early Christians, it is well known that the congregations joined in chanting different parts of the Liturgy, that is, the Psalms and Hymns—a fact which implies simple and easy Music, sung without preparation, by persons who, generally speaking, were uninstructed in the Art, and who moreover professed to observe the greatest simplicity. This was the earliest step to the destruction of ancient Music; another was the method in which it was first set in the Christian Churches to barbarous prose, and to not less barbarous poetry. Thus the rhythm of their Music derived from their words retained but little mark of measure, and was probably drawled out in slow and unequal time to a language without harmony. It still, however, had constituted rules and variety in its change, and character sufficient to render it capable of being applied to other kinds of performances. The Music of the first four centuries of the Christian Church is not precisely known. At the end of that period, we learn from St. Augustin* that Ecclesiastical chanting was in so great confusion that St. Ambrose, Archbishop of Milan, in 374, undertook the task of reducing it to some order.

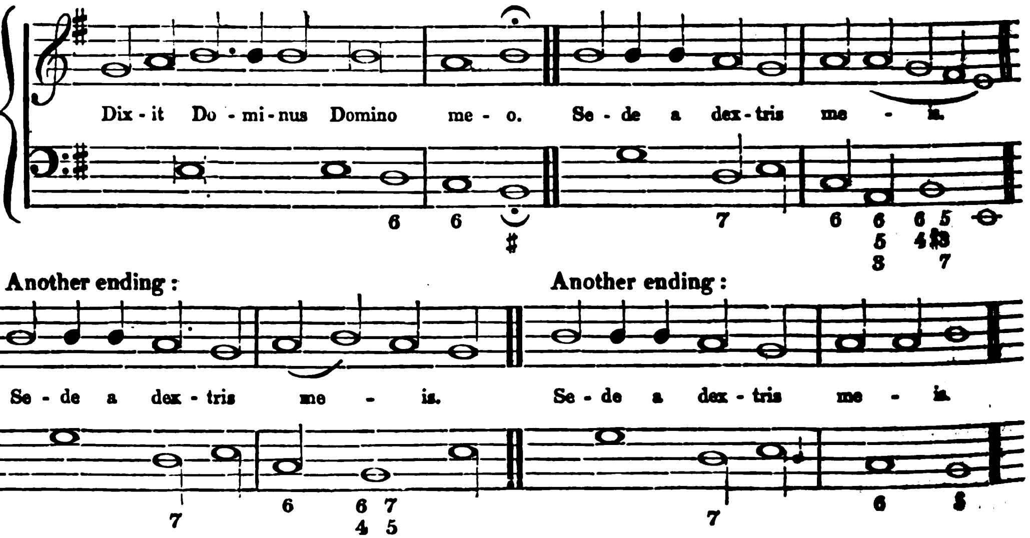
Pope Gregory.

To that Prelate the Church was indebted for laying the foundation of a superstructure executed by Pope Gregory two centuries afterwards, which has formed, in its turn, the basis of all that is grand and valuable in modern Art. The Gregorian Ecclesiastical tones, still used in the Churches of Italy in their early simplicity, first made the Italians the chief singers of Europe, and they may with equal truth be said to have been the origin of Music in our own Country. The modern chant of our Cathedrals, introduced at the Reformation, is but a poor substitute for that which, confined to nine varieties, has, without satiating the ear, been heard in the Romish Church from the time of Gregory to the present hour.

Ecclesiastical Tones.

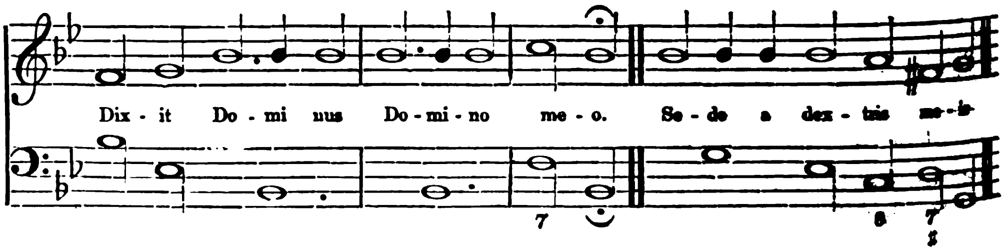
The following are the Gregorian tones.

1st Tone


Dix - it Do - mi - nus Domino me - o. Se - de a dex - tris me - is.
6 6 ♯ 7 6 6 5 3 6 4♮3 5 7
Another ending:
Se - de a dex - tris me - is.
7 6 6 4 ♮3 7 5
Another ending:
Se - de a dex - tris me - is.
7 6 ♮

Before proceeding to give the remaining tones, we shall here briefly notice that the first four are in minor, and the latter four in major keys, and further, that the 1st, 3d, 5th, and 7th are called authentic tones, that is, not rising higher than an octave from the key note, and rarely descending below it. The remainder are denominated *plagal*, and do not descend *lower* than the octave to the tonic or key note, nor rise *higher* than the fifth to it; hence it ought to be a rule with the organists of the Catholic Church, that in giving out the authentic tones, a key should be chosen so that the final note may be in the lower part of the compass of the singer's voice, and for the plagal tones one in which the final may be in the middle of it.

2nd Tone


Dix - it Do - mi nus Do - mi - no me - o. Se - de a dex - tris me - is.
7 6 7 ♯

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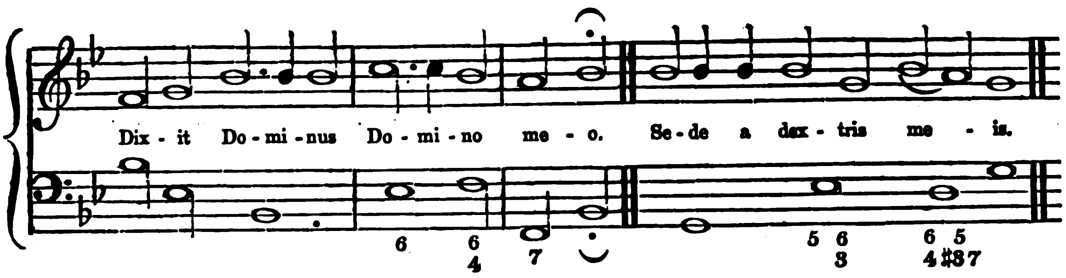
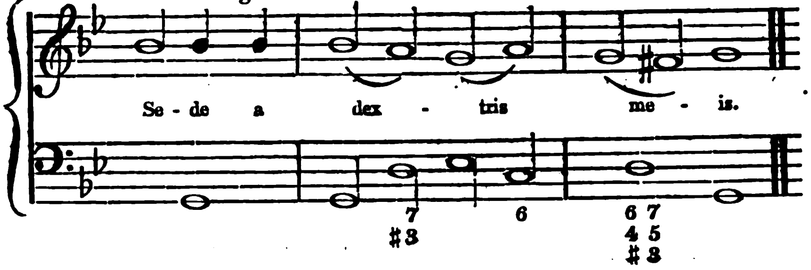
* *Confess.* ix. c. 7.

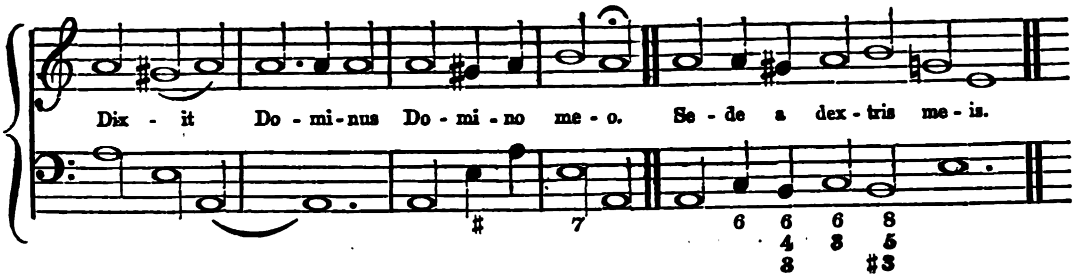
3rd Tone


Dix - it Do - mi - nus Do - mi - no me - o. Se - de a dex - tris me - is.
6 6 4 7 5 6 3 6 5 4 ♯3 7

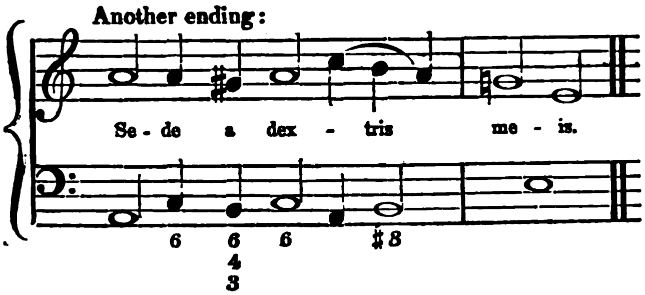
Another ending:



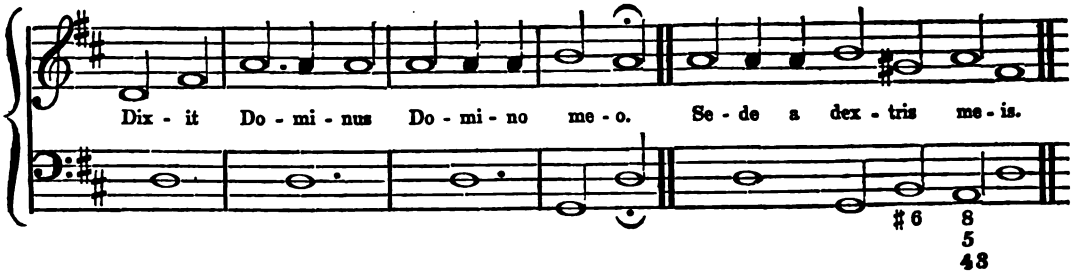
4th Tone


Dix - it Do - mi - nus Do - mi - no me - o. Se - de a dex - tris me - is.
♯ 7 6 6 4 3 6 3 8 5 ♯3

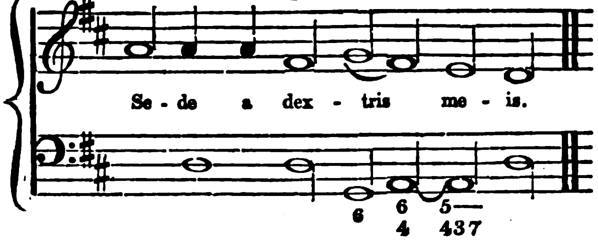
Another ending:



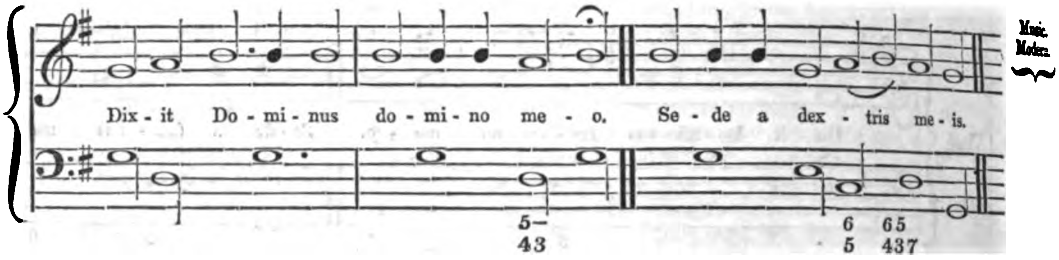
5th Tone


Dix - it Do - mi - nus Do - mi - no me - o. Se - de a dex - tris me - is.
♯6 8 5 4 3

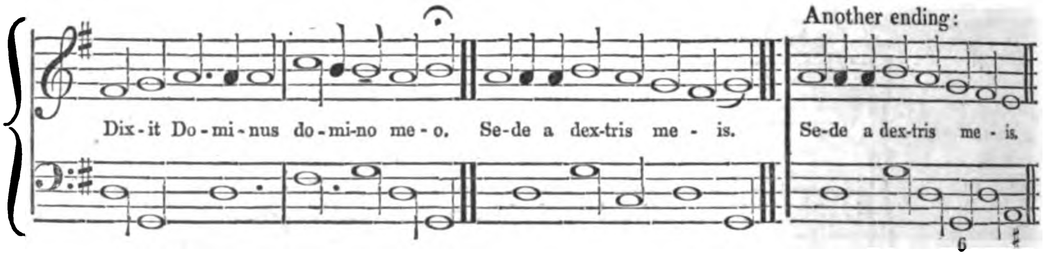
Another ending:



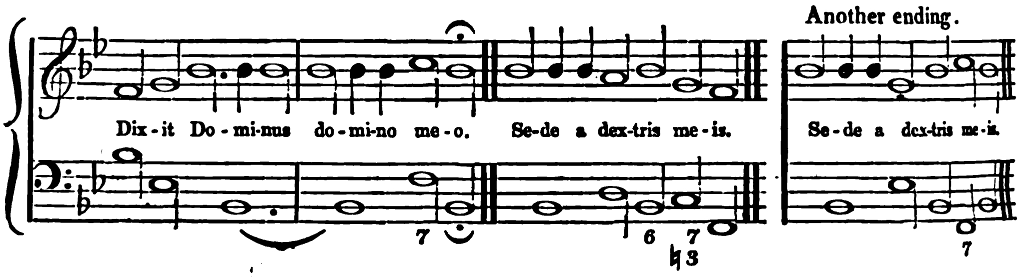
6th Tone


Dix - it Do - mi - nus do - mi - no me - o. Se - de a dex - tris me - is.
5–
43
6
5
65
437

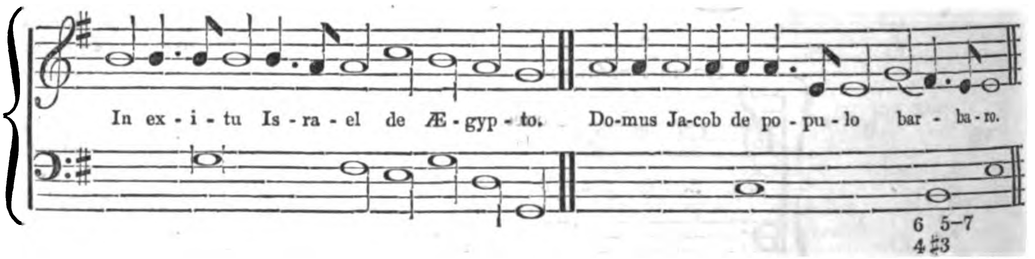
7th Tone.


Dix-it Do-mi-nus do-mi-no me-o. Se-de a dex-tris me - is.
Another ending:
Se-de a dex-tris me - is.
6

8th Tone



8th Tone Irregular

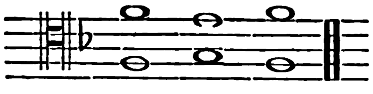

In ex - i - tu Is - ra - el de Æ - gyp - to. Do-mus Ja-cob de po - pu - lo bar - ba - ro.
6 5–7
4♯3

The above are the groundwork of the Antiphons, Hymns, and Masses of the Gregorian Music, which, as we have above observed, still command the veneration of the Roman Catholic, and impress the cultivated Protestant ear with admiration. The harmonies show how susceptible such a system was of richness. Gregory was not, however, satisfied with having formed this code of doctrinal Music, but maintained and ensured its duration by establishing a school for orphans, who were educated as singers for the different Christian Churches.

Musical scale of Guido.

It does not appear that the Musical scale assumed any form resembling that which it bears at present before the beginning of the XIth Century. We are indebted for it to Guido, born at Arezzo, a little town of Tuscany, about the year 990; duly to appreciate whose talents we must recollect, that between the decease of Gregory and the period whereof we now speak, the attempts to improve Musical notation were many. The practice had been to place letters on syllables to indicate sounds, neither a very intelligible method, nor one quickly read. To place them, therefore, at different degrees of height from each other, indicating the proportionate elevation or depression of the voice, those degrees being accurately marked by parallel lines, was no slight improvement. Though this mode had indeed been in some measure used before the time of Guido, it is to him we are indebted for its simplification and order. He wrote it at the beginning of the line, and when the note occurred merely put a dot in its place. And this method he afterwards improved, by placing dots in the intervals between the lines, to denote degrees, by which the scale was rendered much easier to perform at sight. Guido added to the system then in use a bass note, answering to our *g*, or *sol*, in the Fa, or bass clef, which he designated by the gamma (Γ) of the Greeks, and from this the series of sounds in the system takes the name of *gamut*. Beyond these improvements he proceeded to that of counting by hexachords instead of tetrachords, and of marking by the syllables *ut*, *re*, *mi*, *fa*, *sol*, *la*, the major hexachord, however placed in degree upon the system. This foundation of his system of solmization, we have not room to explain further. The invention of counterpoint has, without justice to former Musicians, been assigned to him. Notwithstanding he first wrote on the subject, he is not entitled to its invention, though it had made little progress before his time. The following appears its origin. The organ introduced into France as early as the year 757, soon became general in the Western Churches. Used as an accompaniment to the voice, it was at first in unison with it, and the facility it afforded of giving several sounds at the same moment of time soon afforded the opportunity of discovering that among them there were some which, when simultaneously struck, produced sensations agreeable to the ear. The minor third appears to have been one of those first remarked, and thence generally used at the close of an air, but there were many other modes soon afterwards in use, such as holding the sound of the organ on a note below the plain chant, or *canto fermo*. Other harmonies were also used which (without detailing those employed by several authors previous to Guido, as Notker, Remi, Hucbald, and Ado de Cluny) show the origin of the Art, and at the same time prove that it was totally unknown to the Ancients. Those who are inclined to pursue this subject, will do well to consult the Abbé Gerbert's two Works, *De Cantu et Musicâ Sacrâ*, &c. 2 vols. 4to. 1774, and his Work in 3 parts, 4to. published in 1784, and bearing the title of *Scriptores Ecclesiastici de Musicâ Sacrâ potissimum*, &c. Up to the period we have arrived at, the *canto fermo*, or plain chant, consisted of notes of equal duration as respects time, and rhythm was unknown. Perhaps from the circumstance of profane Music containing a portion of that quality, or from Musicians beginning to feel its importance, so that the organ and the voice might move together, this branch of the Science now began to receive some attention. Franco of Paris, some say of Cologne, was the first who treated on this subject. Though his birth-place is uncertain, it is by no means so that he was a Scholar of the Cathedral of Liege in 1066. Before him, the attempts at this part of the Art, he says, had been fruitless, and it really appears that he was the first who reduced the rules of rhythm to a system. His Work is printed in Gerbert's collection above mentioned. His doctrine is, that measured Music is superior to plain chant, and he alludes to three measures of a note, the long, the breve, and the semibreve, whose subdivisions we omit, as well as his marks of relative rests and pauses. He gives five modes of rhythm, which are the elements of his Rhythmopœia. Descant he defines as the union of several melodies concordant with each other, though consisting of different figures. In his maxims an obvious progress appears, and most particularly in the use of the major or minor sixth between two octaves; being the earliest example in the records of the Science, as under:

ranco.



For a century after the time of Franco, Music, as respects harmony, appears to have remained in the same state which it occupied about the period of the Crusades, when Europe was otherwise engaged than in prosecuting the Arts. Walter Odington, a Monk of Evesham, and Robert Handlo, the latter of whom flourished more than a century after the former, are the only authors of the period whom it is necessary to name. Towards the close of the XIIIth Century, a commentator on Franco arose, who appears with somewhat of the claim of inventor, a Paduan of the name of Marchetti, among whose writings we find one on plain chant, in 1274. A Work of his on Measured Music was dedicated to Robert, King of Naples, whose reign was from 1309 to 1344. Descant had made some progress at this time, and we now find the first use of chromatic passages, as in the following examples :

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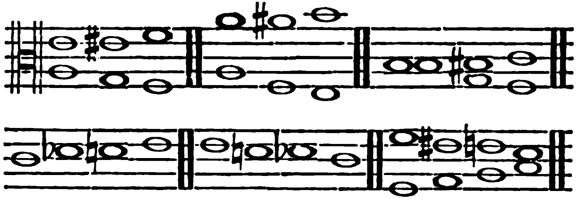


This author gives a theory, and treats at some length of chromatic and enharmonic genera. Certain, indeed, it is that the Art had then considerably advanced; as is proved by the writings of John de Muris, a Doctor of the Sorbonne, whose Country is undetermined; and who, but for the researches of M. Gerbert and Dr. Burney, would have had the credit of these inventions, particularly of rhythm and the form of notes. Though the science of harmony is much indebted to his exertions, it does not appear that he did much towards the advancement of Musical notation. It was he who first noticed the impropriety of two consecutive perfect consonances by similar motion, and who, moreover, laid down many laws respecting the succession of intervals which are observed at the present time; and in his Works the term *counterpoint* is first used instead of *descant*. A great variety of opinions appears to have been entertained about this time respecting the laws of counterpoint, inasmuch as the Doctor complains of the continual changes in the Art of Music.

John de Muris.

XIVth Century.

About this period, A. D. 1322, John XXII. issued a Bull countermanding the further use of descant in the Church because of the abuses into which it had degenerated, and its want of fixed principles. There is, however, at the end of it a saving clause to the following effect:—"It is not our intention wholly to prevent the use of concords in the sacred service, particularly on great festivals, provided the ecclesiastical chant or plain song be carefully preserved." John de Muris is supposed to have been living so late as 1345. Franco and he had many commentators, among whom were Philip de Vitry, of whom nothing more is now known than his name, and Prosdocimus de Beldemandis of Padua, who was a Professor of Music in that City in the year 1422, and whose writings are now lost; this latter is said to be the first who admits to a place the minor sixth in the catalogue of concords, and who speaks explicitly of the fourth as a discord. He, however, says it is less a discord than the second or seventh, and may be placed in a middle class between concords and discords. We may here notice that the name of Philip de Vitry frequently occurs in ancient authors, especially in England. Morley tells us, that he used red notes in his motets to imply a change of mode, time, and prolation. Vitry does not, however, mention this in his Tract on Counterpoint, and "his motets," says Burney, "such is the transient state of Music, would be utterly unintelligible," though Morley tells us, that "they were for some time of all others best esteemed and most used in the Church." From the XIIIth to the close of the XVth Century, there is a hiatus in the history of counterpoint. Perhaps this will not excite our wonder when we know from Durand, (*De Modo Gen. Concil. celebrandi,*) that at the latter end of the XIIIth Century, motets were considered indecorous and profane; and that Carpentier gives a passage from the MS. Constitu-

Prosdocimus de Beldemandis.

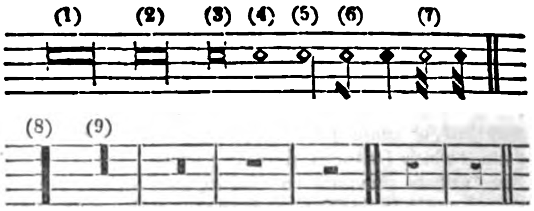
Philip de Vitry.

tions of the Carmelite Friars, ordaining that "no motets or other songs, that are more likely to excite lasciviousness than devotion, should be sung under severe penalties." The name of motet has been for centuries past, and is still given to all compositions for the use of the Catholic Church, such as Psalms, Hymns, Anthems, &c. The discoveries of M. Perne among the Manuscripts of the Royal Library at Paris, justify a hope that the interesting interval presenting the gap we have mentioned may be still filled up.

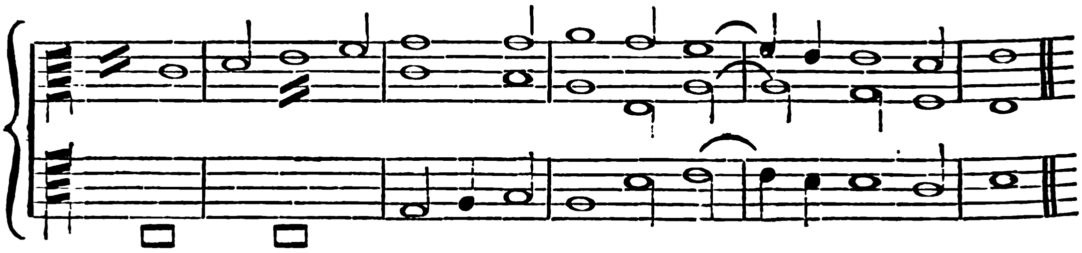
XVth Century. About the close of the XIVth Century, the rhythmical feet of Franco began to lose ground, and the sounds introduced into the measure or metre were as many as the subdivision of the different orders of notes would at that time permit; this induced new forms or figures to represent new values of time, which were introduced towards the close of the XIVth and beginning of the XVth Century. They are not, indeed, mentioned in the writings of the period, but that they were instituted and fixed is certain, from our finding them in authors of a later date, and especially in the Works of John Tinctor, Chapel-master to Ferdinand, King of Naples, and afterwards Canon Doctor at Nivelle, in Brabant, and who consequently lived in the latter half of the XVth Century. Among other Works this author left a Dictionary of Music, under the title of *Definitorum terminorum Musicæ*. The doctrines found in Tinctor are, however, much better displayed in the Works of Franchino Gafforio, a writer who forms a very memorable epoch in the History of Music, not only on account of the extent, but the durability, also, of his doctrine. Born at Lodi in 1451, in 1484 he became Chapel-master of the Cathedral of Milan, and Professor at the School of Music in that City. Of the Works which he left, that which is best known to the World is the *Pratica Musica*, printed at Milan in 1496, and almost one of the first Musical Treatises that issued from a printing-press. Its division is into four books, whereof the first treats of harmony, which then, as with the Ancients, signified little more than air; the second is on measured chant; the third on counterpoint; and the last on Musical proportions. The first has no novelty, but the second and third are interesting. Respecting the value of notes, Gafforio considers five as essential, and these are the five principal notes, namely the maxim, (1,) the long, (2,) the breve, (3,) the semibreve, (4,) and the minim. (5.) There are lesser values, the semi-minim of two sorts, *viz.* the major seminim (6) and the minor semi-minim. (7.) Each of these has a corresponding rest, the long having two, one denoting perfection, (8,) the other imperfection. (9.)

Tinctor.

Gafforio.



The relative value of these notes to each other is denoted by different terms. That of the maxim with the long is called the major mode, that of the long with the breve the minor mode, that of the breve with the semibreve is called time, and that of the semibreve with the minim prolation. At an earlier period this prolation was called minor prolation, and that of the minim to the semi-minim major prolation. Each of them may be perfect or imperfect, that is, triple or double, and the quoties is signified by different signs, and these relations being quite independent of each other, allow of almost infinite combinations. We find from Glareanus that those in which all the relations were double were in most general use; and secondly, that in which all are doubled except time; the first corresponding to our common time of two, and the second to our measure in triple time, using figures of double value; the remainder are included in our compound measures with a similar modification. In this, then, the system of values is fixed, excepting some slight modifications to be hereafter noticed. Gafforio's third book is divided into fifteen chapters. The first two treat in a general manner of counterpoint and its different sorts; the third contains eight rules for the succession of consonances, much the same as those now used; the fourth chapter is on dissonances, and sufficiently proves that those intervals were employed in the time of the writer, though with much circumspection, not longer than for the value of a minim, in passages and by syncope, and this but rarely. On this point he mentions various composers who made use of them without any scruple, as Dunstable, Binchois, Dufay, Brasart, &c., and concludes by stating that many of these intervals may be used with propriety. The fifth and sixth chapters are on fourths, showing how they were used at that period; the seventh relates to sixths and thirds, and the remaining chapters to the arrangement of the different parts. Though Gafforio gives no details respecting the form of Musical pieces of his time, we know from John Tinctor that canons were then in use, and were called fugues, and that even enigmatical canons were known. Music was also divided into spiritual and profane, the former called *motet*, the latter *cantilena*. The compositions of this era, for so it may be denominated, and others rather later, display talents worthy of investigation.



When the Western Empire was destroyed and dismembered by invasions from the North, Music consisted only of the Ecclesiastical chant and the national melodies of the Barbarians; and in these was found the first distinction between the serious and ideal style. The popular songs of the Middle Ages, composed by the Troubadours, successors, as it were, of the ancient Bards, such as Raoul de Concy, Thibaut, Count of Champagne, and others, give a correct notion of the ideal style, whilst the serious style was restricted to plain chant, and the harmonies composed on it. At this period counterpoint made rapid strides, canons led on to fugues, and much art became required for composition. According to the testimony of Tinctor, England can claim the honour of having supplied one of the principal contributors to the revolution that took place in the Art. The passage which confers on the English a principal share in the invention of figurative harmony is as follows. *Cujus, ut ita dicam, novæ Artis fons et origo (Contrapuncti) apud Anglos, quorum caput Dunstaple extitit, fuisse perhibetur.* The writer goes on to enumerate his contemporaries in France, as Dufay and Binchois, who were immediately succeeded by Okenheim, Busnois, Regis, and Caron, *omnium*, he says, *quos audiverim in compositione præstantissimi.* The John of Dunstable above mentioned appears to have died either in 1453 or within five years afterwards. Tinctor wrongly attributes the invention of measured chant to John, and he has been followed by Sebastian Heyden, who wrote in 1537, and afterwards by Nucius, who adds to those above named many others who were certainly later, such as Josquin des Prez, H. Isaac, L. Senfel, B. Ducis, &c. Of this period we know of not more than one canon, which is given by Burney, and is a tolerable composition.

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Of the Works of the ancient masters of the French and Flemish Schools, about 1480, and subsequently, many examples have reached us. L. Guicciardini accounts the Flemish as the older School, and says that it furnished all Europe with singers and composers. Guicciardini, however, must not be strictly relied on: he was a renegade Italian, who settled at Antwerp in the service of the Emperor Charles V., and in his History of the Low Countries determined on giving the people among whom he lived the honour of every useful and ornamental invention to flatter his patron, even at the expense of his native Country. So the Abbé du Bos, from a contrary principle, wished to give the honour to the Flemings in order to steal it from them afterwards in favour of France, his own Country. Among the most celebrated masters of the Flemish School were James Obrect, or Hobrecht, J. Ockenheim, but especially Josquin des Prez. Obrecht, the earliest, taught the celebrated Erasmus Music. He was born in the Netherlands in 1467, and Glareanus says, that so great was his facility in writing that he composed a Mass in one night, which was very much admired by the learned. It is not certain at what period Ockenheim died, but he is generally considered a composer of the XVth Century, as there is no proof of his existence in that following. He composed a motet in thirty-six parts, but of what they consisted, or how they were disposed, is not told by Ornithoparcus or others who mention the circumstance. This, however, was surpassed at rather a later period by our own Countryman Bird, who composed one in forty parts, whereof a copy is in possession of the writer of this Essay. The celebrated Josquin des Prez, or as he was styled in Latin Jodocus Pratensis, was the scholar of Ockenheim, and was universally considered by his contemporaries as the best composer of his time. His compositions for the Church, though long laid aside, and now obsolete through the change in notation, still deserve the attention of the curious. Burney says of him, "The laws and difficulties of canon, fugue, augmentation, diminution, reversion, and almost every other species of Musical contrivance allowable in Ecclesiastical compositions for voices, were never so well observed or happily vanquished as by Josquin, who may justly be called the father of modern harmony, and the inventor of almost every ingenious contexture of its constituent parts near a hundred years before the time of Palestrina, Orlando di Lasso, Tallis, or Bird, the great luminaries of the XVIth Century." He was a singer at Rome, afterwards Chapel-master to Louis XII. of France, and died about 1520. After him may be placed Pierre de la Rue, or as he is called in Latin Petrus Platensis, a very voluminous writer of the period. Walther says he was a Netherlander; Glareanus a Frenchman; others give Spain as the place of his birth. He certainly was a learned contrapuntist, and many of his compositions for the Church are still extant, some of which were published immediately after the invention of Musical types, in the year 1503. He made free use of the four principal discords, the second, fourth, seventh, and ninth. B. Ducis and other composers followed Pierre de la Rue, and up to the time of Orlando di Lasso maintained the honour of the Flemish School.

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Pierre de la Rue.

B. Ducis.

French School. Brumel.

The most ancient contrapuntist of the French School was Anthony Brumel, a contemporary of Josquin and scholar of Ockenheim. Without much invention, his harmony is pure, and his melody and notation clearer and more simple than is generally found in the writings of his day. Glareanus says, that at the beginning of the XVIth Century, at an extreme old age, he composed a *Kyrie eleison*, in competition with Josquin, wherein not only in the tenor, but in all the parts ascending and descending, he introduced the subject with wonderful skill. Brumel may be considered the founder of the French School of Music. Anthony Fevin, a native of Orleans, is mentioned by Glareanus as a successful emulator of Josquin. John Mouton is claimed by Guicciardini as a Fleming, but it is certain that the greater part of his life was spent in the service of the French Court, during the reigns of Louis XII. and Francis I. He was the scholar of Josquin and master of Adrian Willaert. Arcadelt, Verdelot, L'Heritier, Goudimel, and others followed, of whom our limits confine us to the mere enumeration. In Germany, about the same period, appear H. Finck, H. Isaac, L. Senfel, and others. The collections by Peutinger, Bodenschaft, and others, make us acquainted with the names and Works of more than two hundred composers who flourished between 1450 and 1580, to whom fugues and the most intricate compositions were mere amusements, written with singular ease and correctness.

Fevin.

Mouton.

Germans.

English Music from XVth Century to present time.

XVth and XVIth Centuries.

It would be improper to omit in this place a concise view of the progress of counterpoint in our own Country, and we will premise by stating that there are Masses in four, five, and six parts, composed by Englishmen, which are as ancient as those of the Continental writers; as also secular Music of two and three parts, in good counterpoint, of the XVth and beginning of the XVIth Century. Among our early composers are William of Newark, Sheryngham, Edmund Turges, Tutor or Tudor, Gilbert Banester, Browne, Richard Davy, William Cornyshe junior, Syr Thomas Phelyppes, and Robert Fayrfax. Little, however, is known of these Musicians. Turges was one of the Musicians of Henry VI. Tudor was the author of several compositions in Prince Henry's (Henry VIII.) Music Book. Cornyshe was in the Chapel of Henry VII.; and Fayrfax was admitted to the degree of Doctor of

Henry VIII.

Tye.

Music at Cambridge in 1511. In the reign of Henry VIII. we have not only the Monarch himself a clever Musician, as is manifest from the Anthem under his name in Boyce's Collection of Cathedral Music; but the names of Kasar, Ashton, Nonman, Shepherd, Dr. Christopher Tye, whose *Laudate nomen* is still sung and admired, and is in truth a magnificent specimen, Johnson, Parsons, and others, which point out the extent and success with which Music was cultivated in England. From the Earl of Northumberland's (Henry Algernon Percy, fifth Earl) *Household Book*, it appears that this Nobleman, as was the practice with others, retained a regular Musical retinue. One of the items runs thus, "My Lorde usith and accustomyth to gyfe yerely to every Erlis (Earl's) Mynstrellis, when they custome to come to him yerely, iij*s*. iiij*d*. Ande if they come to my Lord seldome, ones in ij or iij yeres, then vj*s*. viij*d*." It is clear that great attention was paid here to Choral Music during this King's reign, for among the "Ordinaunces made for the Kinges Houshold and Chambres" by Wolsey, it is said, that "when the King is on journies or progresses, only six singing boys and six Gentlemen of the Choir shall make a part of the Royal retinue; who daylie in absence of the residue of the Chapel, shall have a Masse of our Ladye before noon, and on Sondaies and holidaies Masse of the daie, besides our Lady-Masse and an Anthempne in the afternoon; for which purpose, no great carriage of either vestiments or bookes shall require." In 1550 the whole of the Cathedral Service was set to Musical notes by John Marbeck, organist of Windsor, and printed by Richard Grafton.

Marbeck.

Marbeck was a zealous Reformer whose enthusiasm was near being the cause of his martyrdom in Henry's time; he was condemned to the stake for heresy, but pardoned at the intercession of Sir Humphry Foster. As it can scarcely be said that England could ever boast a School of Music, it will be more convenient in this place to follow up a succinct account of its history and our best authors from the period above named, before we proceed to notice the Italian, German, and French Schools.

Elizabeth.

Elizabeth, in the early part of her life, appears to have studied Music, and a long and generally tranquil reign, in spite of the fanaticism of the times and the outcry of the Puritans, allowed it to be brought to a pitch of perfection here, through the diligence and talents of Tye, Tallis, Bird, Morley, and others, scarcely surpassed by that of Italy itself.

Tallis and others.

Yet it would appear that the parsimony of the Sovereign in rewarding Musical talent was such, that Drs. Bull and Dowland, two master spirits in the Art, quitted the Country in pursuit of better encouragement on the Continent.

James I.

James I. came from a part of the Island, which, notwithstanding the splendid talents it has exhibited in Literature and the other Arts, cannot be recognised as having hitherto produced a good Musician. This Prince received no pleasure from Music. In his reign the names that appear are those of Dr. Nathaniel Gyles, Thomas Tomkins, Elway Bevin, and Orlando Gibbons in Ecclesiastical Music. For the chamber, principally madrigals, besides the above, we had Michael Este, Thomas Este, Bateson, Pilkington, Litchfield, Ward, Wilbye, Farmer, Bennett, Ford, and others.

Gibbons.

It would be unjust to the memory of Gibbons, whose splendid compositions are still used in our Cathedrals, and will never be surpassed, to withhold the testimony of Dr. Tudway to his genius; he says that his services and "anthems are the most perfect pieces of Church composition;" and again, that his "fugues and embellishments are so just and naturally taken, as must warm the heart of any one who is endued with a soul for divine raptures." He died in 1625, being commanded, as organist to Charles I., to attend the marriage of his Sovereign with Henrietta of France at Canterbury, and having composed the Music for the occasion in that City, he was there attacked with the small-pox, and dying on Whitsunday, was buried in the Cathedral.

Madrigal Society.

We regret that our space does not allow us to enlarge further on the merits of the writers above mentioned; the Musician, and especially the Madrigalian, well appreciates the encomiums, though passing, which it is our duty to pay them, and it may be interesting to the reader to be aware, that there still exists in the Metropolis a Society, founded about a century ago, whose object is the preservation and performance of the Music of Elizabeth's, James's, and Charles's reigns, and in which he may still occasionally hear sung, as of old, *The Triumphs of Oriana.* This, "the Madrigal Society," is a truly Antiquaries' Society, and worthy of more patronage than it has ever received; having rendered important service to the Art by keeping alive the true and classic English style. We feel pleasure in simply recording the name of John Immyns its founder. It is at present under the presidency of a most worthy and distinguished amateur, Sir John Rogers, of ancient family, and himself a Musical writer of no ordinary abilities.

Charles I.

Charles I., during the life of his father, was a scholar of Coperario, (Cooper,) and, according to Playford, had acquired considerable facility on the viol di gamba. He had much affection for Music, and especially for that of the Church. Hence he encouraged the Art and its Professors.

His band

From Rymer's *Fœdera* we find that his band consisted of Nicholas Lanière, master thereof, who had two hundred pounds yearly for wages, Thomas Foord, Robert Johnson, Thomas Day, Alfonso Ferabosco, Thomas Lupo, John Lawrence, John Kelly, John Cogshall, Robert Tayler, Richard Deering, John Drewe, John Lanière, Edward Wormall, Angelo Notary, and Jonas Wrench. Also Alfonso Bales and Robert Marshe. Among these are the names of some writers whose compositions are known to us; such as Foord, Ferabosco, Johnson, Day, and Deering; but the more celebrated of the reign, such as Dr. Child, Dr. Wilson, and William and Henry Lawes, although honoured with the King's favour, do not appear in the grant. Dr. Child was a good but not extraordinary Musician, and after having been organist of St. George's Chapel sixty-five years, died at Windsor, aged ninety, in 1697. In 1641, John Barnard, a Minor Canon of St. Paul's Cathedral, published and dedicated to Charles a fine collection of English Church Music, consisting of services and anthems; it is to be regretted that it was not in score, each of the parts having been printed in folio separately, and a complete copy of them is not now known. They consisted of morning and evening services, and the communion pieces and responses by Dr. Tye, Tallis, Bird, Morley, Strogers, Bevin, Orlando Gibbons, Mundy, Parsons, Dr. Gyles, and Woodson, with Tallis's Litany, and a considerable number of full anthems in four, five, and six parts, by Tye, White, Farrant, Shepherd, Bull, Parsons, Morley, Hooper, Mundy, Giles, Gibbons, Batten, Weelkes, and Ward. Of this period, although they are not authors of choral compositions, ought not to be forgotten the names of Martin Pierson, Richard Deering, a member of the family of the Deerings of Kent, Christopher Gibbons, Ben Rogers, Matthew Lock, and others. In this reign

Dramatic.

Charter to Musicians.

Dramatic Music appears first in England to any advantage. In 1635 was performed in the Middle Temple, a Masque written by Sir William Davenant, the vocal and instrumental Music being said to have been composed by William and Henry Lawes. In 1639, we find a Masque, *Salmacida Spolia*, written by Davenant, and the Music by Lewis Richard, Master of his Majesty's Music, a name which we do not recollect to have seen on any other occasion. In the 11th Charles I. an extensive Charter was granted to the most eminent Musicians living at the time, incorporating them by the style and titles of Marshall, Wardens, and Commonality of the Art and Science of Musick in Westminster in the County of Middlesex, investing them with great privileges, which were afterwards confirmed in the fourteenth year of his reign. The patent roll of this Charter is tested 15 July, 11 Car., and is in the Rolls Chapel. The powers granted to this Company extended throughout the realm, the ancient claim of the Dutton family over the minstrels of the Palatinate of Chester only excepted. The powers given them were sufficient to sow the seeds of their destruction, which soon occurred.

Suppression of the Cathedral service.

Villiam nd Henry awes.

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ford.

At Oxford during Civil War.

The suppression of the Cathedral service in 1643 was a death-blow to the Music of England. Puritans have no bonds of fellowship with the refined Arts, and the cant and hypocrisy of the times will account for the comparative barbarism into which Music fell in the reigns of James and Charles: the contentions of parties also allow little time and disposition for the culture of the Arts, however indisposed their professors themselves may be to mix in the troubled throng. Thus during the Protectorate, the chief Musicians sought asylums in the houses of private persons, among patrons who were scarcely able to protect themselves. The Musicians selected by Charles were not men of great genius and abilities, yet the King was neither ignorant nor partial in his choice; they were the best the nation could boast at the time. Though on every other point the realm was divided into factions, which were actuated by the extremest violence, there was but one opinion of the merits of William and Henry Lawes. Yet notwithstanding the testimony of Milton, himself, it is presumed, a very fair Musician, we are unable to perceive in the compositions of these men sufficient to justify the panegyrics bestowed upon them. To Tallis, Bird, and Gibbons they were infinitely inferior; indeed, it is scarcely right to name them in the same sentence. The Interregnum from the death of Charles to the Restoration, from the extreme fanaticism of the times, was very unfavourable to Music, yet was it zealously cultivated in private, and among those whose career commenced in this period was John Jenkins, a great composer of *Fancies for Viols*, which were in high estimation during the rude state of Instrumental Music; he was much, and perhaps deservedly, admired at the time, but except a madrigal or two of some merit, his Works are now forgotten. The lovers of English Vocal Music are indebted to John Playford, who, in 1655, published the first edition of his *Introduction to the Skill of Music*, a compendium of Morley, Butler, and other Works. It had so rapid a sale, that, in 1683, it had passed its tenth edition. It contained no novelty in theory or practice, but its form, price, and style were so suited to every class of the Musical world, that it seems to have been more generally purchased than any elementary Tract that had then appeared in this or any other Country. Playford was born in 1613, and was not only a vendor of Music but a good Musician. His publications were very numerous, and his intelligence as a printer of Music, so far secured to him and to his son the esteem of the first masters of the Art, that without a special license, or authority, he appears to have had almost a monopoly of the business of furnishing the nation with instruments, books, and all the tools of the Science. During the period of the Civil War, Oxford was the place of refuge for Musicians, but after 1646, the year in which the King was forced to quit that city after the battle of Naseby, till 1656, all seems hushed. From that time Anthony Wood, a lover of the Art, and for other causes venerable in the eye of the reader, preserved a good account of the state of practical Music in the University. Honest Anthony tells us, "The gentlemen in private meetings which A. W. frequented, played three, four, or five parts with viols, as treble viol, tenor, countertenor, and bass, with an organ, virginal, or harpsicon joined with them;" but he adds, "they esteemed a violin to be an instrument only belonging to a common fiddler, and could not endure that it should come among them for feare of making their meetings to be vaine and fiddling. But before the Restoration of Charles II., and especially after, viols began to be out of fashion and only violins used, as treble violin, tenor and base violin; and the King, according to the French mode, would have twenty-four violins playing before him, while he was at meales, as being more airie and brisk than viols." In truth, at this period instrumental Music, and particularly stringed, had begun to make its way in England. Wood afterwards gives the names of the performers with whom he used to play, as well as a sketch of their moral and Musical qualities. Thus he describes "Christopher Harrison, M. A., fellow of Queen's College, a maggot-headed person and humorous;" "Nathan Crew, M. A., a violinist and violist, but alwaies played out of tune as having no good eare, he was afterwards Bishop of Durham." Thomas Ken, afterwards Bishop of Bath and Wells, used to be of these parties.

Restoration

Charles II. His choir.

At the Restoration, Child, Christopher Gibbons, Rogers, and Wilson, were created Doctors, and were promoted together with Low of Oxford. Child, Gibbons, and Low were appointed organists of the Chapel Royal, and Captain Henry Cook was made master of the children. Gibbons, likewise, held the situation of organist of Westminster Abbey; Rogers, formerly of Magdalen College, Oxford, was removed to Eton. Wilson had places in the Chapel and Westminster Abbey, and Albertus Bryne, a scholar of John Tomkins, was appointed organist of St. Paul's. Thus the choirs throughout the Kingdom were in time supplied with good masters. The organs, which had mostly been destroyed, were not restored without great difficulty, for except Dallans, Loosemore of Exeter, Thamar of Peterborough, and Preston of York, scarcely an organ-builder was left. At this period, Schmidt and Harris, with his son René Renatus, were invited over, and received the homage due to their transcendent abilities. At the Coronation of Charles II., according to the Cheque-book 23d April, 1661, the Musical establishment contained, among others, the following celebrated names: William Tucker, minister; Edward Lowe, William Child, and Christopher Gibbons, organists; Henry Cook, Henry Lawes, Thomas Piers, Henry Purcell, Edward Colman, Gentlemen. Charles, says Tudway, was a brisk and airy Prince, and tired with "the grave and solemn way which had been established by Tallis, Bird, and others, ordered the composers of his Chapel to add symphonies, &c. with instruments to their anthems." This produced a new style of writing, and soon afterwards some of the cleverest children of the Chapel arrived at skill in composition, among whom were Pelham Humphreys, John Blow, and others, to whom the King gave much encouragement; Humphreys and Blow were both fine composers. The latter succeeded Purcell (who first brought Dramatic Music in this Country into repute) at the organ of St. Margaret, Westminster. He was contemporary with another fine writer, John Weldon, and died in 1708, at the age of sixty, leaving a name venerable among English Musicians.

Henry Purcell.

Of Henry Purcell, it is truly said by Dr. Burney, that he "during a short life, and in an Age almost barbarous for every species of Music but that of the Church, manifested more original genius than any Musician under similar circumstances, that my inquiries into the History of the Art have yet discovered in any part of Europe." Henry Purcell was born in 1658. Both his father Henry and his uncle Thomas were gentlemen of the Chapel Royal at the Restoration. As his father died when he was only six years old, it is probable his master was Captain Cook, who continued master of the Chapel boys to the time of his death in 1672. Purcell was organist of the Abbey at the age of eighteen. Humphrey succeeded Cook, and Purcell continued to receive instructions from him till his voice broke. He had a few lessons from Blow, which are blazoned in that Musician's epitaph by the boast of "Master to the famous Mr. Henry Purcell." His powers embraced every species of composition with equal facility. In the Theatre he knew how to produce the utmost effect whereof an orchestra was then capable; in the Church, fugue, imitation, or plain counterpoint, or the expressive style of accompanying the voice with instruments, whereof he was the founder; in the chamber, sonatas for instruments, odes, songs, ballads, cantatas, and catches, were equally easy to him. He became the darling and wonder of the nation, and, till the arrival of Handel, was almost the only composer whose Works commanded attention. He died November 21, 1695, in the thirty-seventh year of his age. Had he lived longer, it is not improbable we might have had to boast of an English School of Secular Music, a collection of which by him was published by his widow two years after his decease under the title of *Orpheus Britannicus*. The public have been recently much indebted to Mr. Vincent Novello, a Musician of the present day of no common abilities, for bringing to light and publication some of the unknown wonders of Henry Purcell, and it is but justice to say, that the editor is worthy of the author.

Composers for the Church after him.

Aldrich.

After the death of Purcell, the chief composers for the Church were, as dilettanti, Drs. Holder, Creyghton, and Aldrich, and William Tucker, as professors, Jeremiah Clarke, Goldwin, Weldon, and Drs. Croft, Green, Boyce, and Nares. Of these men, all eminent, we cannot refrain from singling out, in an especial manner, Dr. Henry Aldrich, appointed Dean of Christchurch in 1689, who was not only profoundly skilled in the theory and practice of harmony, but also distinguished himself as a scholar, a theologian, a profound critic, an able architect, and possessed exquisite taste in Arts, Science, and Literature in general. His compositions for the Church give him a rank among the greatest masters of his time. Besides his numerous original compositions, he adapted English words to the Psalms and Liturgy, to many of the motets of Tallis, Bird, Palestrina, Carissimi, Graziani, and Bassani, originally used for the Roman Catholic service. He sometimes amused himself with lighter compositions, and we apprehend that there are few of our Musical readers who can be unacquainted with the pleasing melody and general effect of his round "Hark the bonny Christchurch bells." Dr. William Croft, a pupil of Blow, was one of the great Musicians of this period; a composer pleasing, elegant, and apparently simple, he frequently rose to the grand and masterly, and he has left scarcely a composition which does not exhibit great genius and learning. His Choral Music was published in two volumes folio, in 1724, under the title of *Musica Sacra, or Select Anthems for two, three, four, five, six, seven, and eight Voices, to which is added the Burial Service as it is occasionally performed in Westminster Abbey*. The Burial Service, which closes the first volume, was composed upon an idea suggested by Purcell who lived only to finish one movement. It is simple counterpoint of note against note, and its solemnity, arising much from its simplicity and the syllabic coincidence undisturbed by fugue, is so admirable that it still retains its place at every Royal and Public funeral in this Kingdom. Dr. Croft died in August 1727, in the fiftieth year of his age, of an illness contracted by attending his duty at the Coronation of George II. He lies buried in the North aisle of Westminster Abbey, in which he held the situation of organist. To Dr. William Boyce the Cathedral Service was, and still is, under great obligations for his *Choral Collections*, which were published in three volumes folio. He obtained great fame as a dramatic and miscellaneous composer, and there is much originality and sterling merit in his compositions. The last Musician we shall name, not from want of numbers but from our space failing us, is Jonathan Battishill, who seems to be the connecting link between the old and present race of English Musicians, amongst whom is to be found much genius for Choral Music, though we regret to say we cannot produce many instrumental compositions from them of equal ability. Battishill died at Islington in 1801, aged sixty-three years, and, according to his last request, was interred near Dr. Boyce in the vaults of St. Paul's Cathedral. This composer and Samuel Webbe may be considered as the founders of Glee-writing, a species of composition confined to this Country, in which we have no rivals, and in which we mention the names of Alcock, Arne, Attwood, Ayrton, W. Beal, Callcott, Dr. Cooke, Robert Cooke, Crotch, Danby, James Elliott, Harington, William Hawes, Horsley, William Knyvett, Thomas Linley, the Earl of Mornington, Shield, Stafford, Smith, Spofforth, T. F. Walmisley, the Wesleys, Charles and Samuel, &c. &c. as having contributed to its perfection.

Dr. Croft.

Dr. Boyce.

Battishill and his successors.

Perfection of the Art on the Continent.

Use of bars.

We shall now return to the consideration of the Art as perfected in other Countries, premising that our observations will be confined to the Musical system and the different styles of composition. According to Glareanus, the most prevalent combination which resulted from the perfection or imperfection of the ancient modes, was that in which the values of the notes were imperfect, that is in a duplicate or subduplicate ratio. This became at length the foundation of all the Musical relations; various modifications succeeded, and these were chiefly brought into use by the invention of bars, which were introduced by composers to render the calculation of corresponding values easier, by enclosing within a given fixed space as many notes of the score as were equal to one note of great duration. Thus at first a bar was drawn only at every eighth or fourth measure. The Works that appeared about 1600, are the first known with any kind of bars; the general use whereof did not obtain till a century after. The distance between the bars gradually diminished till they enclosed but one measure, as in the present time, at which the only exception arises in the *à capella* time, where two semibreves moving quickly are enclosed in one bar to save the frequent repetition of bars. Thus the introduction of bars with their gradual increase has brought notes of great value into disuse, and a bar is now rarely valued by a note of greater duration than the semibreve. The Moderns have multiplied diminished notes in the form of crotchets, quavers, semiquavers, &c., which formerly were scarcely known. Rhythm has sustained little variation, not so with sounds, and consequently harmony and counterpoint.

odes.

In the XVIth Century a change took place which led the Art to its present perfect state. Every one sensible of Musical tones must have remarked that all Musical pieces end in some particular note or sound. This is called the tonic or principal note. If the piece be dissected, it will be found to consist of a number of notes having each a different ratio to the principal or key note. The combination of them constitutes the Musical mode; and by proceeding upwards from it to its octave or eighth, placing each sound in regular succession, the scale of the mode is formed. It is consequently evident that a great variety of systems may be formed from the different modes. In the present day we have but two modes, the major, in whose scale is contained *ut*, *re*, *mi*, *fa*, *sol*, *la*, *si*, *ut*, and the minor, whose ascending scale is *la*, *si*, *ut*, *re*, *mi*, *fa*, *sol*, *la*. It was in the XVIth Century that this system of tones became universally known, and its influence in composition is soon discoverable. It was fully established in the School of Durante at Naples. As regards its theory, Choron maintains, with truth, that it is still imperfect, but this is not the place to enter upon that subject. Had the system experienced no variation, the Science would have attained its limits three centuries ago, and there would have been nothing to add to the labours of Ockenheim, Josquin, Orlando, and the other masters of the French and Flemish Schools. The alterations, however, which took place in the tonal system led to changes in every branch of composition. The early contrapuntists almost invariably added the third and fifth to all the notes of the scale except that which bears the minor fifth, to which they affixed the sixth. All harmony was thought allowable which excluded a succession of fifths and octaves; but the doctrine of the new modes soon exhibited the errors of this sort of harmony, which gave innumerable bad combinations, such as the sixth with the third, or often on other degrees of the scale.

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Charles Montverde, a Schoolmaster of Lombardy, who lived about 1590, was the inventor of the harmony of the dominant, and the first who had the courage to use the seventh and ninth of the dominant without preparation; he also employed the minor fifth as a consonance which had theretofore been treated as a discord. These points admitted, Musicians soon came to the conclusion, that only three essential harmonies were to be acknowledged in the mode, that of the tonic, the dominant, and the subdominant, which are all that should be placed either direct or inverted on those notes as well as those comprised in their harmony. Monteverde also introduced double dissonances, followed soon after by triple dissonances, and diminished and altered chords. Counterpoint was of course affected by these changes, and intervals in melody unthought of before, as well as intervals in harmony entirely original, quickly succeeded each other.

Viadana di Lodi, inventor of fundamental bass.

Viadana di Lodi, about this period, hit upon the process of giving a melody to the instrumental bass altogether different from that of the vocal bass, proposing to make this bass form the groundwork of the piece, and to represent the chord it was to bear in every part by means of figures. Thus, although he added nothing to harmony, he must be considered the inventor of what is called the fundamental bass. These innovations were sometime in gaining ground, but towards the close of the XVIIth Century, the Ecclesiastical tones began to be considered as little more than a form to keep the modern tones within bounds; so at least the Neapolitan School, with Durante at its head, used them, and the modern tones are now universally allowed in the Church. P. Aaron Togliani, and the authors of the first half of the XVIth Century, added little to the improvements of the XVth.

Zarlino.

Zarlino's *Institutiones*, published in 1571, contained the theories and precepts up to his time; but celebrated as his Work has been considered, he seems to have had but a confined knowledge of his contemporaries, inasmuch as he does not appear to have heard of Palestrina, who was at that period in the zenith of his reputation. Zarlino was, however, himself one of the Flemish School, which may account for the silence.

Ceroni.

D. P. Ceroni, in 1613, published at Naples his *Melopeo*. Narrowing the boundaries of Musical doctrine he modified his precepts according to those of Palestrina and the composers of the Roman School, and Galeazzo Sabbatini soon afterwards gave rules for thorough bass on the same principles.

Berardi and others.

The Treatises, however, of Berardi, Buononcini, and Gasparini, at the close of the XVIIth and commencement of the XVIIIth Century, reduced the practices in counterpoint to a regular theoretical system little different from that received at present.

Rameau.

At the beginning of the XVIIIth Century, Rameau, a French writer, gave out that all rules up to his time were merely blind traditions, and proposed to reduce them to a few precepts dependent on the law of Physics. We do not think it useful to pursue the analysis of his doctrines. Nothing can be more erroneous than some of his enunciations; as for instance, that in which he states that harmony will be regular whenever the chords of which it is formed, being brought back to their fundamental chords, offer successions correspondent to the rules he has established; since a survey of the cases in which his method is adopted proves that a fundamental succession of notes may have very bad derived successions, and, on the contrary, from good and usually derived successions fundamental successions arise which he condemns as faulty. His principle met with some success in France, but is now everywhere laid aside, and it was never of any other use than to attract the attention of writers on the theory of inversions. It however produced in France a habit of viewing harmony in a Philosophical manner, and towards the close of the XVIIIth Century it led to the formation of an elementary Work by the Conservatory at Paris, or at least by the Professor of that establishment. (Catel.)

Catel.

Catel considers as natural chords those commonly called consonances, and all dissonant chords used without preparation, he examines their successions and shows how, by means of the anticipations, retardations, and alterations whereof they are susceptible, they generate all artificial chords or dissonances properly so called. This doctrine was not altogether new, inasmuch as it had been taught by the School of Durante, and had also been used in Germany; but Catel placed it in a clearer light, and fixed it for adoption in France, and it may be truly considered an important advance in the doctrine of harmony.

Styles of composition.

Church style.

Respecting the different styles of composition in Music, the principal are usually considered under the heads of Church, Chamber, and Instrumental Music. The first is properly divided by Choron into four species; that *à capella*, the accompanied style, the concertante style, and lastly, the oratorio. That which belongs most exclusively to the Church is the style *à capella*. It was generally written on the tones of the plain chant without accompaniment. It is of four sorts, the plain chant, the fauxbourdon, counterpoint on the plain chant, and Ecclesiastical, fugued counterpoint. Of the plain chant an idea may be formed from the specimen of the Ecclesiastical tones above given, which have undergone no alteration since Pope Gregory's time. The fauxbourdon is the most simple of compositions with many parts, and is with counterpoint of note against note in which the bass bears perfect chords only; it remains still the same as at the time when the rules of composition were firmly fixed, (which is more remote than the Flemish School,) and it is now only used in Psalmody and some few canticles. With the third sort, or counterpoint on the plain chant, is frequently and erroneously confounded the fauxbourdon, but in it the plain chant is strictly preserved, and it consists in forming thereon various other parts displayed with all the ingenuity of counterpoint, such as imitations, fugues, canons, &c.; its history and that of composition are the same. The masters of the Flemish School succeeded in it wonderfully, but it is to Italy we must look for taste, elegance, and grandeur in this style, whereof the finest specimens were produced in the XVIth Century. In France it was soon neglected, and our own experience of the difference a very few years ago between the Ecclesiastical Music of France and Italy would lead to a doubt, did we not know the contrary, whether it ever had existence at all in the former Country. The contrapuntists of the XVth and XVIth Centuries did not restrict themselves to the plain chant as a basis, but frequently employed a plain chant or simple melody of their own as the groundwork; and moreover they soon diverged from the rule of keeping the leading chant to a particular part, and took their successive subjects from the principal features of the plain chant by introducing various kinds of imitations in the parts, and this was, doubtless, the origin of fugue. The sense of the words was neglected, but the Music displayed the talent of the composer and the powers of the singer, and at length proceeded so far that the Council of Trent entertained the proposition of suppressing Music in Churches altogether, and a decree would have passed to that effect but for particular and local considerations. Pope Marcellus, about 1552, considering the extent to which this style was carried, determined on reducing Church Music once more to the simple Gregorian chant, when the young Palestrina presented his Holiness with a Mass in a style entirely new, devoid of tumult and noise, the harmony pure, the style grand and pious, the expression of it sweet yet majestic; all features which characterise the style of the immortal Palestrina, truly called by his Countrymen *Il Principe de' Musici*. This man may be said to have been the founder of every thing valuable in the Art. He was considered by his successors as a model not to be equalled; which feeling, added to a continual change in the foundation of the system, induced them to abandon a style wherein little glory or advantage could be acquired. The decline of the *à capella* style, the varieties of which during the XVIth Century had risen to a height since without parallel, was eminently serviceable to the accompanied style, or that in which the voice is accompanied by the organ alone, and to the concerted style, wherein all sorts of instruments accompany the voice. To trace the origin of these would be rather difficult, and when accomplished, would answer no useful purpose. Choron says that the first has been much influenced by the madrigal style, the second by that of the Theatre; we do not, however, quite coincide with him, thinking it possible that exactly the inverse was more probably the fact. It is, however, but justice to that excellent and learned author, to whom we confess ourselves largely indebted, to allow that there is room for doubt as to the opinion we entertain.

Palestrina.

Oratorio.

The oratorio is a species of drama whose subject is generally some story selected from the Scriptures, or a Religious allegorical piece for performance in a church by singers who personate the different characters of the drama. Choron observes, that the oratorio differs from the sacred drama, inasmuch as though the subject of each may be the same, *the latter* is for the Theatre, the former for the Church. The invention of the oratorio is attributed to St. Philip of Neri, who was born in 1515, and founded the Congregation of the Oratory at Rome in 1540. Wishing to turn to pious account the theatrical enthusiasm which then prevailed at Rome and kept the people from church, especially in the time of the Carnival, he formed the scheme of having sacred Interludes written by good Poets, and of having them set to Music by the best composers, and performed by the most favourite singers. The experiment succeeded; the concerts attracted all Rome, and from the Church of the Oratory, (the Chiesa Nuova,) in which they were performed, obtained the name of oratorios. At first they were short and simple Poems; finally, nothing was wanting to their effect but the pomp of scenery and costume. Animuccia, a contemporary of Palestrina, was perhaps the earliest composer of an oratorio. Their style was at the beginning a mixture of the madrigal and cantata, but in the present day, oratorio compositions differ very little from those of the Theatre.

Chamber Music.

Madrigal.

Berardi and Padre Martini have divided Chamber Music into three styles, namely, simple madrigals, accompanied madrigals, and cantatas; to these Choron adds a fourth style, under the title of fugitive pieces, but we are rather inclined to place these fugitive pieces, such as the canzonette of Italy, the villanelle, &c. the bolero of Spain, the romance and vaudeville of the French, under the head cantata. The madrigal generally, but not necessarily, resembles much the motet and fugue of the Church; the words were latterly, however, of a secular nature. The simple madrigal is for voices only, the accompanied madrigal has, as its name implies, the accompaniment of the organ. Arcadelt has by some been considered the first who composed this species of Music; but the conjecture is without foundation, since madrigals of more ancient masters have reached us, and even by composers of the ancient Flemish School. To those conversant with madrigal writers the name of Adrian Willaert will immediately occur. The truth is that simple madrigals came in about the beginning of the XVIth Century, during which and the whole of the following century the style was particularly cultivated and encouraged; but it has been completely abandoned since the early part of the XVIIIth Century, unless the English glee can be said to be a graft of it, which, perhaps, may be truly advanced. There was much variety in this style. The first madrigals very much resemble the church style, but they afterwards assumed a character peculiar to themselves. The change may be strikingly recognised in the madrigals of Luca Marenzio, but a little after the time of Palestrina, and afterwards in the Works of Gesualdo, the Prince of Venosa, of Monteverde, Mazzochi; and it seems to have been exhausted by attaining its utmost limit in the compositions of the celebrated Alessandro Scarlatti. The accompanied madrigal seems to have originated only after the practice was introduced of placing an instrumental differing from the vocal bass below the voices; a practice which dates from the commencement of the XVIIth Century. The principal writers in this style were Frescobaldi, Carissimi, Lotti, Scarlatti, Clari, Marcello, and Durante. Since these masters, little has been attempted in this style of Music, one which requires great Musical learning and the devotion of years to the study of the Science. Choron says, and perhaps too truly, that the Musician of the present period limits his glory to the composition of a song; nor can we much wonder at it when we reflect on the rewards attendant on Theatrical compositions, as distinguished from those of the Church and Chamber.

antata.

The Cantata, which originates from the Lyric Drama, is a short Poem, which in a literary sense has no very determined character, though generally confined to the recital of some simple interesting passage or fact to illustrate the expression of some peculiar sentiment. It has a wide range, sacred, profane, heroic, comic, and even ludicrous subjects admit its employment. Its invention is assigned to the early part of the XVIIth Century, the first writers of it being Poliaschi a Roman, Loteri Vittorii of Spoleto, and Ferrari of Reggio, better known by the name of Ferrari della Tiorba. After these came Merula, Graziani, Bassani, and Carissimi. Towards the middle of the Century, Marc' Antonio Cesti, a scholar of Carissimi, brought recitative to perfection, Rossi and Legrenzi flourished, and Alessandro Scarlatti surprised the world by the brilliancy and fertility of his genius. In the beginning of the XVIIIth Century, we have Gasparini, Giovanni and Antonio Buononcini, Benedetto Marcello, a Noble of Venice, but more to be esteemed for his well-known compositions of the Psalms to the Paraphrase in Italian of Giustiniardi, Pergolesi, Vivaldi also a violin writer, the Baron d'Astorga, and lastly, Nicolo Porpora, all classical and justly celebrated writers. The remark relative to the decline of madrigal writing equally applies to the neglect of the cantata in the present day. It has been abandoned for nearly three quarters of a century, and perhaps from the same causes. Those who are desirous of pursuing an inquiry into national melodies, which come under the head of Choron's fugitive pieces, will do well, amongst other Works, to consult the *Essai sur la Musique Ancienne et Moderne*, 4 vols. 4to. by J. B. Laborde. Though there are many important errors in it, and the harmonies are bad, the melodies, at least a large proportion of them, may be trusted to.

Music of the Drama.

Early Lyric Drama.

The Lyric Drama of our time is, doubtless, very unlike those representations, both sacred and profane, whereof the ancient writers speak, for we have authority for asserting that such were in existence since the XIIth Century. The earliest which can be identified is an *Orfeo* of Angelus Politianus, composed about the year 1475; and in 1480 a Musical Tragedy is mentioned as having been performed in Rome. It is believed that in 1555, *Il Sagrifizio*, a Pastoral Drama of Agostino Beccari, was set to Music by Alfonso della Viola, for the Court of France, and that an Opera was performed at Venice in 1574, in honour of Henry III. passing through that city from Poland to take the Crown of France, to which he had succeeded on the decease of his brother Charles IX. It can scarcely be supposed that at this period the Lyric Drama had a style peculiar to itself; it was most probably a mixture of the Church and Secular Music of the day; nor was it till the perfection of the recitative that the Drama can be said to have a style of its own, of which the following account is said to be the origin.

Bardi, Strozzi, and Corsi, three Florentine amateurs, dissatisfied with the attempts which in their time had been made to bring Dramatic Poetry to perfection, hit upon the expedient of engaging one of the best of their Lyric Poets to write a Drama which should be set to Music by one of the best Musicians of the period. Rinuccini was the Poet selected, and the subject *Daphne*. Peri applied to it a species of recitation in Musical notes, but without their regular support and marked time. The composition was, in 1597, performed at the house of Corsi, and met success so decided, that Rinuccini determined to write two other Works of similar nature, *Euridice* and *Ariana*. In the year in which the latter was performed at Florence, an Oratorio, entitled *Di Anima e di Corpo*, with the same description of recitative composed by Emilio del Cavaliere, was performed at Rome. This Work, as well as that of Peri, were published in 1608; the two authors claiming in their Prefaces the invention of recitative. G. B. Doni allows the invention to neither, alleging that it belonged to Vincenzo Galilei, father of the celebrated Astronomer, who, as well as Bardi and others, sensible of the defects of the Music of that Age, employed himself in endeavouring to recover the Musical declamation of the Greeks, imagined the recitative, and applied it to Dante's Episode of Count Ugolino. In this style he also composed the *Lamentations of Jeremiah*, and performed the piece himself with the accompaniment of a viol. Giulio Caccini, a young Roman singer, frequented the house of Bardi, and improved recitative; Peri soon became his rival, and both, as Doni says, united in setting Rinuccini's words of *Daphne*. Peri afterwards composed *Euridice*. Claudio Monteverde, of whom mention has already been made, followed hard upon these with the *Ariana*, which was put into recitative by him. Whatever may be the true state of this case, it is certain that of the above Works the *Euridice* of Clari was the first which was publicly performed, and that its representation took place in 1600 at Florence, on the marriage of Henry IV. of France with Mary of Medicis. Nearly the whole of the Opera, Peri's *Daphne*, is in recitative, and the parts to which the word *aria* is prefixed, are scarcely distinguishable from the others by the appearance of air. Up to the middle of the century this observation generally applies.

Opera of Jason.

In the Opera of *Jason*, set to Music by Francesco Cavalli, a fertile writer of Operas between 1637 and 1667, Dr. Burney observes, that the grave recitative began first to be interrupted with the ornamented sort of stanza called Aria. This Opera was set in 1649, yet the airs were insipid, generally minuet time, and varying constantly. The Operas of Cesti exhibit considerable progress. His most celebrated, *La Dori*, first appeared in 1663 at Venice, and was also frequently performed in the other principal cities of Italy. Cesti was moreover a great writer of Cantatas. He has been untruly stated to have been a scholar of Carissimi. At this period the Opera began to degenerate into *Spectacle*, a practice now carried to such an extent that the machinist and decorator in the present day are almost as much admired as the Poet and Musician. An immense number of composers followed those we have named, many of them possessing genius and talents of a high order, such as Gasparini, Perti, Colonna, Lotti, and the celebrated Alessandro Scarlatti, whose pupils Leo, Vinci, Domenico Sarro, Hasse, Porpora, Feo, Abos, and Pergolesi, in the early part of the XVIIIth Century, gave power to the words by making the melody expressive of the sentiment. They were seconded in their efforts by the Poets of the day, such as Zeno and his pupil Metastasio. The next series of composers comprehends a list of names equally celebrated, Jomelli, Piccini, Sacchini, Guglielmi, Traetta, Anfossi, Terradellas, and others. Among the pupils of these Paisiello and Cimarosa appear.

Gluck.

It is to Gluck we owe the perfection of the Lyric Drama; that great master died at the age of seventy-three, in the year 1787. His Opera of *Orfeo* obtained the honour of being the first ever printed in Italy, the brilliant success of which induced the composer and his Poet Calzabigi to unite their talents on the tragic subject of *Alceste*, an Opera first performed at Vienna in 1768. This was printed in 1769, and for the two succeeding years after it was brought out, no other Drama was allowed to be performed at the Court Theatre. The Dedication prefixed to it by himself we shall quote, inasmuch as it explains the previous state of the Science by showing what he thought ought then to be attended to. "When I determined, he observes, "to compose Music for this Poem, I proposed to myself to shun various abuses in composition, that the vanity of singers, or excessive complacency of composers had introduced, and which had rendered the Italian Opera a most fatiguing and ridiculous, instead of a splendid and beautiful spectacle; I endeavoured to reduce Music to its legitimate purpose, which is that of seconding Poetry, in order to strengthen the expression of the sentiments and the interest of the fable without interrupting the action or weakening it by superfluous embellishments. It struck me that Music ought to aid Poetry, as vivacity of colouring, and a happy agreement of light and shade, strengthen the effect of a correct and well-designed Picture, by animating the figures without altering the outline. I have, therefore, never in this Opera interrupted a singer in the warmth of a dialogue in order to introduce a tedious *ritornello*, nor have I stopped him in the midst of a discourse, to display his agility of voice in a long cadence. I have never deemed it requisite to hurry over the second part of an air where it consisted of the most impassioned and important portion of the subject, in order to repeat the words of the first part four times over; or to finish where the sense does not conclude, in order to give the singer an opportunity of showing that he can vary a passage in several ways and disguise it in his own peculiar manner. In short, I have attempted to reform those abuses against which good sense and good taste have so long declaimed in vain. I have considered that the overture ought to prepare the audience for the character of the coming action and its subject; that the instrumental accompaniments should be used only in proportion to the degree of interest and passion of the Drama; and, also, that it is principally requisite to avoid too marked a disparity in the dialogue between air and recitative, in order not to break the sense of a period, nor interrupt in a wrong place the energy of the action. Lastly, I have thought that I should use every effort in aiming at simplicity, and have, accordingly, avoided making any show of difficulties at the expense of clearness. I have set no value on novelty, unless it naturally sprang from the expression of the subject. In fine, there is no rule of composition that I have not willingly sacrificed for the sake of effect." Gluck became the model of his contemporaries, Piccini, Sacchini, &c., and the Art seemed fixed on a firm basis, except as the changes of melody would act on it, in which respect, judging from present appearances, it is impossible to foresee the limit. The improvement of instrumental Music towards the end of the last century caused a sensible change in that of the Drama, by composers introducing into Operatic movements the system of the symphony. Haydn, Mozart, and Cherubini, and since them Weber, Spohr, Rossini, and all the modern School, in some degree have wrought on this plan, which, however, has one disadvantage, namely, that of often suffering the vocal parts, which are truly the principal, to be eclipsed by those which ought to be subordinate.

Haydn, Mozart, and others.

Comic drama.

We have in the above observations confined our notice to the Lyric Tragedy, but it may easily be conceived that the Comic Opera, the Opera Buffa, &c. underwent changes in a similar manner. The earliest Lyric Comedies known are of the XVIth Century, such are the *Sacrifizio* of Beccari, by Alfonso della Viola, in 1555; *I Pazzi Amanti*, in 1569; *La Poesia rappresentativa*, 1574; *La Tragedia di Frangipani*, by Claudio Merula; *Il Re Salomone*, 1579; *Pace e Vittoria*, 1580; *Pallade*, 1581, &c.; *L'Anfi—Parnasso*, by Orazio Vecchi, 1597, all which were represented at Venice. They are in the madrigal style, which was not very appropriate to the Stage. From the want of instrumental accompaniments, monologues, in order to obtain harmony, were sung by several voices; and recitative was at this time unknown in Lyric Comedy. Many Comic Operas were produced during the XVIIth Century, without entering on the details of which, were we acquainted with them, we arrive at the era above-mentioned when Scarlatti and his pupils infused expression into Dramatic Music. Among them, Pergolesi distinguished himself by the introduction of declamatory modulation into Dramatic Music. Although the masters generally wrote Lyric Tragedy as well as Comedy, Niccola Piccini, was particularly celebrated for the latter, and surpassed his contemporaries in his *Buona Figliola*. Comic Music was enriched by the genius of Guglielmi, Paisiello, and others, but all became eclipsed by the splendid productions in this style of Mozart, upon which to the present period all composers have more or less founded their productions.

Instrumental Music.

Different nstruments.

Instruments may be divided into stringed, wind, and vocal, as respects their sonorous properties; into six species, as respects their mechanism, namely bowed, wind, keyed, stringed, percussible, and mechanical instruments. At the head of these must be placed "the human voice divine," the most beautiful, as well as the type of them all. We shall not enter further on this part of the subject by inquiring into those instruments used among uncivilized nations, but confine our notice to those employed by the educated Musician. These are the violin, viola, or tenor violin, the violoncello, or bass, and the double bass, bowed instruments. The German flute, clarionet, oboe, bassoon, horn, trumpet, trombone, serpent, fife, and flageolet, wind instruments. The harpsichord, spinet, pianoforte, and organ, keyed instruments. The harp, guitar, lyre, and mandolin, stringed instruments. Drums of different sorts and cymbals, instruments of percussion; and, lastly, the bird or hand organ, and bulafo, or Barbary organ, mechanical instruments.

ngle usic.

Single Music is that specially composed for a single instrument, whether produced by that one instrument, or to increase the effect accompanied by one or more instruments in addition and subservient to the principal one. This is the *solo* and *accompanied solo*, whereof the concerto is the more refined and brilliant species. The style of a solo of course is dependent on the extent and nature of the instrument, hence there are as many styles of solos as there are instruments; but as the violin is the principal instrument in the orchestra it will be useless to notice any other; and in our remarks we shall merely touch upon some Historical points relative to the construction of studies, fantasie, capricci, sonate, concerti, &c.

astruc- t.

The construction of solos, simple or accompanied, includes their melodic form and the choice of the instruments employed. The former is still subject to change, and without fixed rules. The same holds with the choice of the instruments, from the Sonata, the simplest, to the Concerto, the most complicated. Corelli seems to have been the person who fixed the bounds of the sonata, which first appeared during the XVIIth Century. Torelli, his contemporary, invented the Concerto bearing the title of *Concerto grosso*, employing at first but five instruments, namely, the quartet, with the leading or principal part superadded. Benda and Stamitz added wind instruments to these compositions, and thus laid the foundation of the symphony. In instrumental Music, as in singing, great changes have taken place, both as respects taste and style. They have doubtless been much influenced by the co-existing styles of vocal composition. When Dramatic Music first rose under the hand of Corelli, it was dry and scientific. Expression was given to it by Geminiani. Under Tartini it attained a very high degree of expression, both in composition as well as execution. Of Tartini, Burney observes that he was the principal Italian theorist of the last century; and that though his system of harmony has been confuted in the scientific part, yet there are frequently found in his writings such admirable ideas, traits of modulation, and curious harmony, as are invaluable to practical Musicians. Soon after Tartini's time, the Concerto was greatly improved, particularly by Jarnowick, (the favourite violin pupil of the celebrated Lulli,) who died at Petersburg in 1804, and by Nicolo Mestrino, twelve of whose Concertos were published at Paris in his lifetime, and who died in 1790, at the age of forty-nine. Both these, however, were far surpassed by Viotti, who gave the Concerto a character peculiarly his own, and brought it to a degree of perfection which seemed incapable of being surpassed; yet the writer of this Essay, who had the good fortune at an early period of his life to hear that master, has since heard several players, Kiesewetter, Baillot, and others, who have left Viotti far behind.

Concerted pieces.

What has been said of solos applies also to Concerted pieces, by which is understood instrumental Music with different parts, which are all equally obligato, from each having its appropriate part, and taking up the strain in its turn, the other parts then becoming accompaniments. These two methods are practised equally in the duet, trio, quartet, quintet, and other Music, where each instrument has its separate part; also in the symphony, where the parts are multiplied in number for effect, according to certain proportions. Boccherini, who died at Madrid in 1806, at the age of sixty-six, was the first (1768) who gave to the trio a fixed character; after him came Fiorillo, Cramer, Giardini, Pugnani, and lastly Viotti. To Boccherini we are also indebted for the quartet as now fixed, in which he was followed by Giardini, Cambini, and in another School by Pleyel, Haydn, Mozart, Beethoven, and many other celebrated men. Boccherini also composed the quintet, and has been surpassed by others as well as by Mozart and Beethoven.

Symphony.

The Symphony, much improved since the middle of the XVIIIth Century by Gossec, Toeski, Wanhall, and Emmanuel Bach, was brought to perfection by Haydn. Mozart and Beethoven have equalled him, but, all things considered, we can scarcely admit that he has been surpassed by those surprising writers. Thus within the space of three centuries (from 1550) all parts of the Musical system, namely melody, the principles of Musical construction and design, and every species of composition, have arrived at a degree of excellence hardly to have been hoped, and perhaps not to be excelled.

Of the different Schools.

The Italian.

Padre Giambatista Martini, in his *Saggio Fondamentale Pratico di Contrapunto*, published in 1774, reckoned five great Schools in Italy, namely, the Roman School, which comprehends Palestrina, the two Nanini, Orazio Benevoli, and Francesco Foggia; the Venetian School, comprising Adrian Willaert, Zarlino, Lotti, Gasparini, and his scholar Marcello; the Neapolitan, in which the leaders are Radio, the Prince of Venosa, Leo, and F. Durante; the Lombard School, including Porta, Monteverde, Parmegiano, and Vecchi; and, lastly, the Bolognese School, comprising Rota, Giacobbi, Colonna, and Perti, to whom Sarti and the Padre Martini himself may be added. The general divisions, however, of the Schools are of Venice and Lombardy, of Rome and Bologna, and of Naples. All the Schools of Italy are characterised by a profound knowledge of the principles of the Science, added to much grace and expression, nevertheless each School has peculiar features of its own. Thus the first has been distinguished by energy and strong colouring, the next by science and purity of composition, and the last by great vivacity and true expression. From the time of Gregory downwards, Italy has always been the cradle of Music, though it was in an exhausted state during the period of the Middle

Ages, when the Country was the scene of continual wars; and it is observable that from the XIIIth to the XVIth Century, the greatest improvement in the Art was attributable to the French and Flemings; the School of the latter, which was in truth the foundation of all that afterwards existed in Europe, having been destroyed and ruined by the Wars in Flanders towards the close of the XVIth Century. The French, from their proximity to and intercourse with the Flemings, partook of their Musical taste, and at that time the Italian chapels, even at Rome, were constantly supplied with singers from Flanders and Picardy, and the compositions of the writers of those nations were continually sung. Naples and Milan invited them, and a great uniformity in Music existed in all the nations of Europe. Though the Italians followed the same principles, the fact of none of their Works of that period being quoted, proves that they then cultivated the Art with little success. Italy began to show its powers about the middle of the XVIth Century, at which period Palestrina appeared, but he went into France to study, where he was the pupil of Goudimel, and afterwards became the head of the Roman School. The Italians owe their excellence to ancient Ecclesiastical counterpoint, to which, having received it from the Flemings, they were the first to give sentiment. They invented phrases and melodic periods, and moreover created tonal harmony, in which latter respect they were so superior to other nations, that the chord formed by the second and leading note of the mixed mode has long been called the Italian sixth, from its being generally believed that the Italians were the inventors of it. They likewise brought counterpoint to perfection, and it is to them that fugue, canon, and all intricate counterpoint owe their chief beauties, and though all the Schools of Italy seem to have had a share in the work, the greatest fame attaches to those of Rome and Naples. It was in Italy that Chamber Music at an early period rose to so high a pitch of excellence, that it seems almost exclusively to belong to that Country; whether it consist of madrigals, cantatas, canzoni, or the like, it flourished in Italy full of grace and beauty. The Theatrical style almost exclusively belonged to Italy. It first appeared at Florence, and was raised to perfection at Naples, having been previously attempted by all the other Schools. In short, the Italians have achieved every sort of vocal composition, and have moreover been, even in instrumental composition, the instructors of Europe, for to them are we indebted for the best models in that branch of the Art. From the Sonata to the Concerto they invented all the species of instrumental Music. Corelli, Tartini, and their pupils cleared the path for the writers of other Countries in violin Music. So with regard to the harpsichord from Frescobaldi to Clementi. It must, however, be conceded, that though Boccherini by the invention of the quintet led the way to that of the Symphony, the Italians have no claim to it.

Vocal performers of Italy.

The great superiority both in execution and numbers of the singers of the Schools of Italy over the rest of Europe is worthy of inquiry, if our space allowed us to indulge in speculation on the subject. Choron says it arose from three causes, the two first whereof belong to them exclusively, and the third is the natural consequence of the others; namely, the climate, the organization of the inhabitants, and the excellence of their rules; and we are inclined to give credit to his supposition at all events of the two latter grounds. Haydn said that the climate of Germany injured the voice of Italian singers, and that he frequently sent those belonging to Prince Esterhazy's Chapel to Italy to improve their organ.

Instruments.

In addition to the violin and harpsichord,—on the former of which Corelli, Tartini, and Viotti, and on the latter Frescobaldi and his School, instructed all Europe,—the Italians invented and brought into use the bassoon, the trombone, as well as many other instruments. In the present day, and perhaps it has always been the case in Italy, instruments are considered only as the means of accompaniment, and, except at Naples, we doubt whether a difficult Symphony could be well performed. Certain it is, that the writer of this Essay never had the good fortune to hear one executed in a way above mediocrity, but he allows that he never witnessed a *public* performance of one. The number of their composers is nevertheless very great, all well instructed, though musical theory is confined chiefly to the amateur.

Present state.

Since the latter part of the last century there seems a considerable decay in the Music of Italy in the number and excellence both of composers and performers. Singers of the first and second rank were always to be found in abundance; and composers, though not in equal numbers, were yet sufficient to mark the Country as the nursery of Music. Now, we rarely have more than two or three singers of the first order, though the number of the second may perhaps be equal; and good composers are no less scarce. Choron attributes this to the preference given to Dramatic Music, to acquire considerable fame in which a profound knowledge of the Art is not requisite, however useful it may be. Italy, however, still preserves a high rank in respect of her Music relatively to the other nations of Europe, and can boast of eminent writers, and it is in that Country that the best vocal instruction may yet be obtained.

The German School.

Numerous Schools.

In Italy, as in Germany, there are almost as many Schools as Capitals. The Italians prefer pure, the Germans brilliant harmony. The German and Flemish Schools are nearly coeval in their origin, hence the German is even prior to the Italian Schools. Germany was the scene of so many Wars towards the close of the XVIth and commencement of the XVIIth Century, more especially the Thirty Years' War, that the Arts were entirely neglected in that Country during the above period. It is certain that Germany was then far behind Italy, and that it was not previously to the end of the XVIIth Century, that Keyser, who was born at Leipsic in 1673, and composed one hundred and seven Operas, gave an impulse to the Germans, which it would seem they are destined never to lose. Since the renewal of the Art, the Germans have followed the Italians in all that regards the foundation of the system. They have not perhaps equalled them in vocal Melody, but in instrumental Music they have surpassed, and continue to surpass, all other nations. The Gregorian chant was of course imported from Italy, but the Germans have a peculiar species of Music called *Chorals*, in which the whole congregation joins with most imposing effect. Their counterpoint, fugues, canons, and all that depends on plain chant, are not to be compared with those of Italy. In Church Music of the accompanied style, the Masses of Graun, Haydn, Mozart, and Beethoven, leave all others far behind. Nor are their Oratorios, such as the *Ascension* by Bach, the *Death of Jesus* by Graun, the *Messiah* by Handel, and the *Creation* and *Seasons* of Haydn, in any degree inferior to their Church compositions. Choron classes the *Creation* and *Seasons* under the head of Cantatas, and denominates them as belonging to the Chamber style, but we do not concur with him, however we may be called to account for our presumption in differing from so learned and competent a writer.

Theatre.

Though not so early as the Italian, the German Theatre is of ancient standing; but it attained little celebrity, till at the close of the XVIIth Century Keyser began to compose for the Theatre at Hamburgh, then in a flourishing condition. Few of his Works remain; he was, however, an industrious composer. Fancy and originality were the characteristics of his Works, and the vigour of a fertile imagination is discernible in all of them. Hasse grafted the manner of the School of Naples on that which Keyser had introduced. Thus improved, it became with some modifications and the later improvements in instrumental accompaniments, the style of Graun, Naumann, Gluck, Haydn, and even of Mozart.

Instrumental.

It is from its instrumental Music that the German School has acquired all its lustre and reputation. On the violin, though the composers of Germany trod in the steps of Corelli, their success entitles them to the rank of inventors. Whilst Locatelli and Geminiani, Corelli's most distinguished pupils, were spreading his School in Holland and England respectively, Benda and Stamitz had begun in Germany, and their successors, Leopold Mozart, Fraenzl, and Cramer were improving the state of violin Music in a surprising manner. So on the harpsichord, Kerler and Froberger, who taught in the French and Italian Schools, were succeeded by men whom to name is sufficient eulogy; we mean John Sebastian Bach and his children, Haydn, Kozeluch, Mozart, Dussek, and Cramer, besides many others. So with respect to their wind instruments a species of composition was introduced which appears almost exclusively in Germany. In instrumental concerted Music the names of Haydn, Mozart, and Beethoven have already been mentioned, and the first especially as being almost the inventor of the Symphony. To these may be honourably added, Weber, Spohr, Hummel, and many others of our own time. A practice which has long subsisted, and is not met with in any other Country, has greatly contributed to the spread of Music in Germany. In all the Public Schools, as well in villages as in cities, Music is taught to children at the same time at which they teach them to read and write; and it is remarkable, that wherever the Jesuits had Schools and Colleges, they engaged with great activity in this branch of education, whilst in no other Country was the Order given to patronize the Fine Arts. The learned Lami, who many years since published a Periodical Journal at Florence, was one day showing a friend the sights in that City. At the celebrated Gallery of Pictures at the Palace Pitti, the stranger said to him, *Voilà le berceau des arts*, to which Lami replied, pointing to a Convent of Jesuits close by, *Et voilà leur tombeau.* But it was a principle with the Jesuits wherever they were established, to accommodate themselves as much as possible to the pursuits of the Princes and People, and on their fixture in Germany having found Musical instruction there universal, they encouraged it as much as possible. Another circumstance which has much contributed to the great progress of Music in Germany, has been the enlightened view which almost all their Sovereigns have taken of it even by their own compositions and practice.

Musical literature.

In Musical literature the Germans have produced a considerable number of excellent Works. Not to mention numberless Treatises on ancient and Church Music, as well as controversial Works on counterpoint, we will cite the *Gradus ad Parnassum* of Fux, dedicated to the Emperor Charles VI., and printed at Vienna in 1725, lately, if not still, the elementary Work used in the Schools of Italy; Marpurg's *History of Music;* many Treatises by Kirnberger and others, such as E. Bach, Matthison, Knecht, Vogler, Albrechtsberger, Forkel, Gerbert, Nickelman, and Koch.

French School.

Music neglected in France at an early period.

During the XIVth and XVth Centuries, the progress of the French in the Arts was very slow, and particularly in that of Music. But in the reign of Francis I. there existed as many celebrated Musicians in France, as in Italy, Germany, Flanders, and England. Those, however, who distinguished themselves in France, were not Frenchmen. Both Orlando di Lasso and Claude le Jeune belonged properly to the Flemish School. So also did Josquin de Prez, who was much esteemed at the Court of Louis XII., and to whom the early Music of France is under great obligations. A curious anecdote is told of a composition by Josquin, which is published in the *Dodecachordon* of Glareanus. Being engaged to teach Louis singing, that Monarch being extremely deficient in flexibility of voice, defied the master to write a piece of Music in which he could possibly sustain a part. He did, however, compose one, a canon of two parts, to which he added two other parts, one whereof had to sustain only one note, the other passing only from the key note to the fifth. Of course, he gave the Monarch the choice of parts, who out of modesty chose that with the single note.

Early composers.

Antoine Brumel, a contemporary of Josquin, and like him a pupil of the celebrated Ockenheim, is the earliest composer of counterpoint in the French School. At this period, the French were behind other nations in writers on the theory of Music, as well as in composers. This state, from the death of Francis I. to the end of the reign of Henry IV., may doubtless be fairly attributed to the internal troubles of the Country. Certon, Master of the children of the Sainte Chapelle of Paris, in 1546, published thirty-one of the Psalms of David in Music of four parts. In a collection of motets published at Venice, about 1544, one appears also by Certon, to the words *Diligebat autem eum Jesus.* This is in five parts, and in it the tenor sings the plain chant of a prayer to St. John repeated upon the key note and its fifth (after a rest of two bars) from the beginning to the end of the piece. A little after this, Didier Lupi set to Music his *Chansons Spirituelles;* Guillaume Bellen, *Canticles*, in four parts; Philibert Jambe de Fer, *the Psalms of Marot;* Pierre Santome, the *whole of the Psalms;* and Noë Faigneut *songs, motets, and madrigals*, in three parts. The name of Crespel also appears in the best collections of motets and songs published in the middle of this century, some of which prove him to have been a profound master of counterpoint. Ronsard, whose poetical fame extended through the reigns of Henry II., Francis II., Charles IX., and Henry III., was extremely partial to Music, and sang very agreeably. His Poetry was set to Music, especially by Antoine Bertrand, who published the collection in 1578, in four parts, and by François Reynard, in four and five parts, in the following year. Ronsard died in 1585, and his funeral, at which Cardinal Perron pronounced the oration, was so pompously celebrated and so numerously attended, that the Cardinal de Bourbon and many other Princes and Nobles could not pierce the crowd. The Music was composed expressly for the occasion, not in plain chant, and accompanied by instruments. The most celebrated Musician of the reign of Charles IX. was the unfortunate Claude Goudimel, massacred among the other Protestants at Lyons, in 1572. Though a native of Franche-Comté, he lived all his life in France, and certainly belongs to the French School. Up to the close of the XIXth Century, a few other names, but of less merit, occur, such as Jean de Castre, Louis Bisson, Nicholas Duchemin, François Roussel, Jean Pervin, Nicolas de la Grotte, Jean Chardavoine, writers of madrigals, and also Jean Serven, who set the Latin Psalms of Buchanan in four, five, six, and eight parts. But France derives little Musical reputation from any of their compositions. Henry III., in 1581, on the marriage of his favourite, the Duke de Joyeuse, with Mademoiselle de Vaudemont, the Queen's sister, lavished great expense in fêtes, balls, and diversions. It was on that occasion that Claude le Jeune wrote his Ballet, *Ceres et ses Nymphes*, a spectacle then new to France. The Music to the dances was composed by Beaulieu or Baltazarini, and Salmon. François Eustache de Caurroy, born in 1549, received from his contemporaries the title of *Prince des Professeurs de Musique*. He was Master of the Chapel to Charles IX., Henry III., and Henry IV. There is extant of his composition, a Mass for the Dead, which was formerly sung once in every year at the Cathedral Church of Nôtre Dâme in Paris, and a posthumous Work, published in 1610, entitled *Mélange de la Musique d'Eustache de Caurroy*. During the short reign of Henry IV. France had scarcely recovered from the horrors of her Civil and Religious Wars. His son, who ascended the throne at the early age of six years, was in his youth much attached to Music. The principal composer of Church Music during the reign of Louis XIII. appears to have been Arthur aux Couteaux, but the best writer of secular Music was Jean Baptiste Boesset, and he was the favourite at Court. The best account of French Music during this reign is to be found in the *Harmonie Universelle* of Mersennus, a large folio volume, published at Paris in 1636.

XVIIth Century.

Dramatic Music.

Ottavio Rinuccini, a Poet who came into France with Mary of Medicis, gave the French their first notion of the Lyric Drama. None, however, are mentioned as having been performed during the reign of Louis XIII., his Minister Richelieu rather patronizing the literary French Drama. Mazarin was the person who first caused an Italian Opera to be heard in France, which was performed at the Louvre in 1646; and out of this sprang the French Opera. Perrin, Master of the Ceremonies to Gaston, Duke of Orleans, in 1670, aided by the Musical talents of Cambert, brought out the first French Opera, under the title of *Pomona*, at the Tennis Court in the Rue Mazarine. Two years after this, Lulli obtained the privilege of performing them, which he enjoyed till his death in 1687. Lulli, born of obscure parents, near Florence, in 1633, was brought by the Chevalier de Guise into France at the age of thirteen years, on account of his Musical talents. He was received into his patron's house among the officers or servants of the kitchen, upon which Ginguené observes, *C'est un pays passablement barbare, que celui où reconnaissant dans un jeune homme un talent distingué pour les beaux arts, on le place parmi des cuisiniers et des marmitons.* Louis XIV. desired to hear him play, and was so pleased with his performance, that he engaged him in his service. Lulli commenced his services by the composition of Ballets for the Court, which gave so much satisfaction that the King would listen to no other than his Music. When the Opera sprang up, Perrin surrendered his privilege to Lulli, who entered into an engagement with Quinault, to furnish him with the words of an Opera every year. The result of this engagement was the production of the Operas of *Les Fêtes de l'Amour et de Bacchus*, *Cadmus*, *Alceste*, *Thésée*, *Atys*, *Isis*, *Proserpine*, *Persée*, *Phaeton*, *Amadis*, *Roland*, and *Armide*. At the time that Lulli was placed at the head of the band of *les petits violons*, very few Musicians in France were able to play at sight, and a person was accounted an excellent master, who could play thorough bass in accompaniment to a scholar. He contributed greatly to the improvement of French Music, which up to his time was infinitely surpassed, especially in sacred Music, by the English masters. In his overtures, he introduced fugues, and was the first who in chorusses made use of the side and kettle drums. It is astonishing that the French were so long stationary in Music after his death. From the production of his last Opera in 1686 to 1733, when Rameau brought out his first Opera, it would have been thought a mad enterprise to have endeavoured to surpass Lulli. The names of the composers who filled up this interval, though obscure, are less so than their Works. Colasse, Lulli's disciple, finished, in 1687, his Opera of *Achille et Polixène*, of which the first act only was found among Lulli's papers. Between that time and 1706 he composed eight Operas for the Académie Royale. During the same period, Charpentier, Desmarest, Campra, Coste, and Destouches, of whom Campra and Destouches were the most celebrated, wrote Operas. These were succeeded by Bertin, in 1706; Mouret, in 1714; Montéclair, in 1716; Rebel and Francœur, in 1725; Blamont, in 1731; Brissac in 1733, in which year Rameau brought out his first Work. Rebel and Francœur continued, however, to compose together till 1760. During this period Instrumental Music was very slow in its progress. The best organists in France during the XVIIth Century were the father, son, and grandson Bournonvilles, and the three brothers Couperin; Chambonières, who died in 1670; Dumont, also a good composer of Ecclesiastical Music, who introduced into it violin accompaniments, by the desire of Louis XIV.; the Abbé de la Barre, so great a favourite of the King, that the situation of organist which he held was at his decease divided between four organists who did the duty quarterly; lastly, Lalande, who began to flourish in 1684, and was the best writer of Sacred Music in France towards the close of the XVIIth Century and the commencement of the XVIIIth. We proceed to one who formed an epoch in the French School.

Lulli.

Rameau.

Jean Philippe Rameau, born at Dijon in 1683, having grounded himself at an early age in the rudiments of Music, left his native Country and wandered about with the performers of a German Opera. At the age of eighteen he composed a Musical entertainment which was represented at Avignon. He then became a candidate for the situation of organist of the Church of St. Paul, in Paris; failing in which attempt he almost determined to decline that branch of his profession, when the offer of the place of organist to the Cathedral Church of Clermont in Auvergne prevented him. In retirement in that City, he pursued the theory of the Art with great industry, having there written his *Traité de l'Harmonie*, printed at Paris in 1722, and his *Nouveau Système de Musique Théorique*, at the same place in 1726. But his most celebrated Work is the *Demonstration du Principe de l'Harmonie*, in which his Countrymen say, he has shown that the whole depends upon one single and clear principle, namely, the fundamental bass; and their admiration has carried them so far as to compare him in this respect to Newton, who from the principle of Gravitation assigned reasons for some of the most remarkable phenomena in Physics; hence they style Rameau the Newton of Harmony. His first Opera was *Hippolyte et Aricie*, in 1733, between which year and 1760 he composed twenty-two Operas. Rameau died in Paris in 1764. He was doubtless a philosophical artist, and it is no small testimony of his merit that Handel always spoke of him in terms of great respect. From the few Works by him which it has fallen to our lot to have heard, we cannot say that he is to our mind a pleasing composer. He is accused of having pilfered his best airs from Italy, which rather a severe critic says he did not quite smother by his barbarous art. His contemporaries and successors in the Opera, and the last of the true French School, were Mondonville from 1742 to 1758, Berton 1755 to 1775, D'Auvergne 1752 to 1773, and Trial 1765 to 1771. To these may be added, La Borde, Floquet, J. J. Rousseau, Duni, and Philidor. After whom came Monsigny, Gossec, and Grétry, who completed the improvements in French Lyric Comedy. The contemporaries and imitators of these latter were Martini, Delayrac, Champeia, and others. The reform which had now commenced in the French Music, was consummated on Gluck's producing in Paris, in 1774, his *Iphigène*, which was soon after followed by other Works of that master. His rivals were Sacchini and Piccini. After these came Vogel, Lemoyne, and others. The galaxy of celebrated men whom we have already named, were followed by French composers of very splendid talents, the principal of whom, in Serious Opera, were Berton, Le Sueur, Catel, and Mehul, and in Comedy the same, with the addition of Boildieu, Eler, Gaveaux, Kreutzer, Plantade, Persius, and Solie. France became, also, the resort of Germans and Italians, such as Cherubini, Della Maria, Nicolo, Steibelt, Spontini, Tarchi, and Winter, who succeeded to a great extent on the French Theatre.

In concerted Music we can scarcely allow the reputation to France which some are inclined to claim for her. It must, however, be conceded, that the quartets of Davaux, and the symphonies of Gossec, preceded in France those of Haydn. In Music, for single instruments, they are justly entitled to our praise Latterly, fresh attempts have been made, but in such as we have heard, we do not think with enough success to require particular notice.

Instrumental and vocal execution.

The French School of the present day demands more attention for its merit in the different branches of execution than for any other point. Choron distinguishes their excellence in this respect by three epochs. That of Lambert in the time of Louis XIV.; of Rebel and Francœur in the time of Louis XV.; and lastly, the modern epoch, wherein the style bears a close analogy to that of melody, or an Italian style, so modified as to be suitable to the French Language. Each of these periods had celebrated singers. The first had Boutilon, the second Jelyotte, the third Garat, Chardini, and others. But the instrumental style in respect to execution, and especially on the violin, is that in which the French particularly excel. Instrumental Music is still studied with great ardour by the French, and on the violin they are at present unrivalled in Europe; the same may be said of their success on the piano-forte, with a few exceptions. But on the organ we can scarcely believe they ever had a performer who could place his hands on the keys in competition with our Samuel or Charles Wesley, or Novello, and many of that School. Their orchestras are magnificently arranged; to compare them with those of Italy would be no compliment to a Frenchman; but when the reader is assured that they surpass those of Germany, where instrumental Music is so highly cultivated, he may form some idea of the value of their Conservatory, which is the nursery of their performers.

Musical Literature.

Choron, the best authority on the point, observes, that the Musical Literature of France is of little value; he says, that among her Works of this kind, some were compiled by artists who knew not how either to think or write, and are as vicious in their principles as in their plan. That others, edited by learned men, or literati, ignorant of the Art, teach only systems and errors. He excepts, however, the methods which concern execution, and particularly those published by the Conservatory of Paris; also in respect of composition, the *Treatise on Harmony*, by Catel, who was a pupil of Gossec, printed in 1802, and adopted by the Conservatory, a Work now very generally received and appreciated throughout Europe. It contains a theory which appears a simplification of Rameau's, but is, in fact, the result of more observation. Choron's own Work, entitled *Principes d'Accompagnement des Ecoles d'Italie en société avec le Sieur Fiochi*, Paris, 1804; and his great Work in 3 vols. folio, Paris, entitled *Principes de Composition des Ecoles d'Italie adoptés par le Gouvernement Français, &c.* deserve our acknowledgments for the use which we have made of them. Of the last, the Editor of the *Quarterly Musical Review* truly says, "If the books on theory which our English harmonists have given the World, condense and simplify the information contained in Choron's valuable and elaborate Work, they bear no sort of comparison with the abundance of precept and example it contains."

PART II.

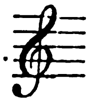
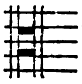
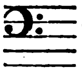
Music.

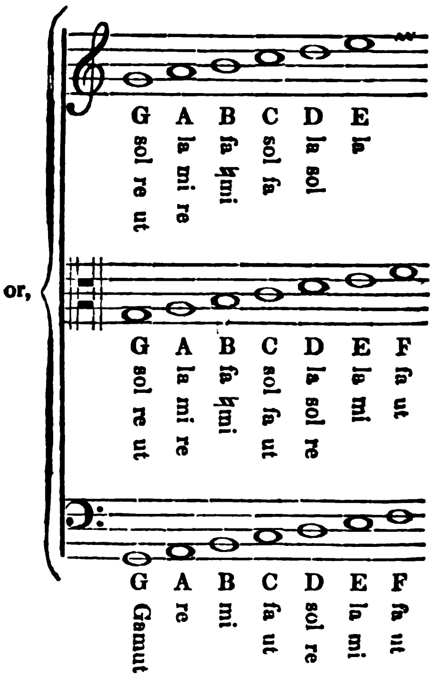
Gamut.

Notation.

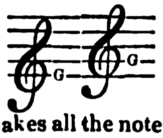
The gamut is a scale or table, believed to be the invention of Guido of Arezzo, upon which the *notes* in Music are placed. It has also been called the harmonic hand, because Guido at first used to arrange his notes upon the fingers of the hand. Some have said that it is not properly the invention of Guido, but an improvement upon the diagramma, or scale of the Grecians, and that his intention in calling his first note Γ, gamma, was to indicate that he took his scale from the Greeks. For this purpose parallel horizontal lines were necessary for the notes to rest upon, and a group of five of these lines constitute what is called a *staff*, the lines and spaces whereof are reckoned from the lowest upwards. The true knowledge and understanding of the gamut is of course the foundation of all Musical learning. The names given to the notes are six in number, *ut, re, mi, fa, sol, la*; the first the foot or gamma of the scale. The moderns have used as equivalents, (by the introduction of *clefs*, which are marks at the beginning of the lines of a song,) the first seven letters of the alphabet, *viz.* A, B, C, D, E, F, G, repeating these in the same succession as the notes move upwards; but the whole will more clearly appear by inspection of the following scheme or diagram.

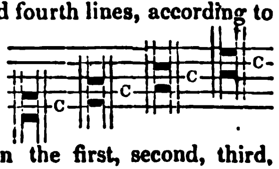
Music

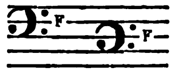
		CLEFS.							
Treble, or Highest.	E								la
	D							la	sol
	C							sol	fa
	B							fa	♮mi
	A						la	mi	re
	G						sol	re	ut
Tenor, or Mean.	F						fa	ut	
	E					la	mi		
	D				la	sol	re		
	C				sol	fa	ut		
	B				fa	♮mi			
	A			la	mi	re			
	G			sol	re	ut			
Bass, or Lowest.	F			fa	ut				
	E		la	mi					
	D		sol	re					
	C		fa	ut					
	B		mi						
	A		re						
	Base	Gamma.	ut						

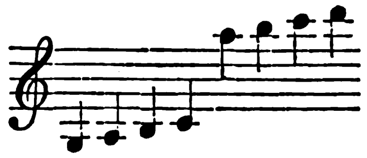


The French have used a seventh syllable, *si*, in their gamut.

It is not our intention in the following pages to use the nomenclature of solmization, but without an introductory table of this sort, it would have been difficult for the reader to have comprehended the nature of clefs and their places; nor would he have been able to understand why the bass clef, on the fourth line, should be called the F fa ut clef; the tenor, on the third line, the C sol fa ut clef; or the treble, the G sol re ut clef; we shall, therefore, in what follows, designate the notes by the alphabetical signs prefixed to them in the diagram. It is, however, here necessary to observe that the situation of each clef, with respect to the line on which it is placed, must be accurately observed, because its position gives its name to the note on the line thus, 

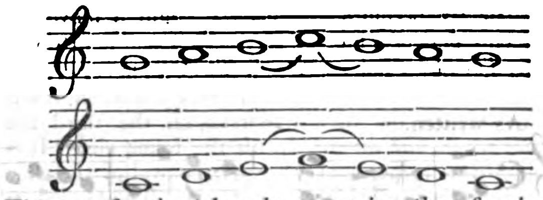
the treble clef placed on the first line, makes all the notes on it G, and so of any other line, though it is rarely if ever placed on any other than the second line, indeed never in the present day; the tenor clef is, however, placed on the first, second, third, and fourth lines, according to the height of the part thus, 

in which case the notes on the first, second, third, and fourth lines are C respectively. The bass clef is rarely used except on the third and fourth lines thus, 

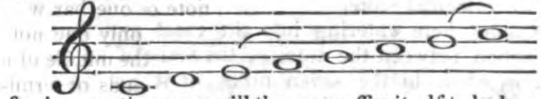
whereon the notes are F respectively, the line between the dots being the place of the note. The utility of these clefs, which are a puzzle to beginners, may be felt in a moment if the reader reflect, that in pieces where many parts are written under each other, the notes correspond with each other vertically, as to the contemporaneous production of each sound, which, in Musical language, is called a *score*. Were there not, therefore, means of representing higher or lower notes than the staff itself would contain in any one of them singly, such a running up and down of the representation of the sounds, (for such are notes,) into each other would occur, that no person would be able to play or sing from it. The clefs, therefore, are nothing more than the means of confining each part as much as possible within the staff. In the old Music the writers rarely exceeded it either above or below, but modern Music has very much exceeded these bounds, especially in the bass and treble parts. In cases in which the notes go out of the staff, in either direction, upwards or downwards, lines are added to contain or receive them thus,  These lines, whether above or below, are called *ledger lines*. When the bass clef is used on the third line it is called the barytone clef, and it was formerly much used in Church Music. It, of course, raised the part in the scale, and made the bass approach nearer the tenor, or mean; it was adapted to a voice not so low as a real bass voice nor so high as a tenor. When the C, or tenor clef, is placed on the first line it is called the soprano clef, when on the second the mezzo soprano, on the third the counter-tenor, and on the fourth the tenor clef. It is evident from inspection that every removal of the clefs upward depresses or lowers the part. The G clef on the first line is rarely found except in old French Music, and is called the high treble. The young Musician cannot have too strong an impression of the importance of a thorough knowledge of the clefs, and that they are merely marks of the places of the notes F, C, and G, without the most perfect acquaintance with which all the splendid Music of the early Schools is closed to him, as well as the power of reading even a modern vocal and instrumental score.

The relative proportions of tones to each other.

Without here entering into the exact mathematical proportion between the notes of the scale of an *octave*, that is, when to the seven notes of it an eighth is superadded, so as to begin a new series, we shall merely for the present observe, that the intervals between the degrees of the scale are unequal, some of them being nearly twice the distance of others. The larger intervals are called *tones*, the smaller *semitones*. The simplest perception we can have of two sounds is that of *unisons*, or notes equal in *pitch*, or acuteness. But this is dependent to sense on the accuracy or education of the ear, and it is necessary to refer it to a standard accessible to mankind generally. Taking therefore homogeneous strings equally stretched under precisely similar circumstances as to heat, moisture, and pressure of the atmosphere, we have a standard of measurement which indicates that the octave or note above the seven of the scale is produced by a string exactly one-half the length of that which gave out the Γ gamma of the system, the repetition of this upwards so as to produce a series of octaves above each other, is too obvious to require explanation. The acute string, or octave, obtains its acuteness or high pitch, from producing two vibrations during the same period that the lower one was engaged in a single vibration, hence the vibrations of the two meet at every second vibration of the upper one. The division of the octave so as to make it ascend agreeably to the ear, (for an equal division of its parts into tones could not be tolerated,) gives a semitone between B and C, and another between E and F. The remainder, namely those between G A, A B, C D, D E, and F G, are whole tones or sounds. Thus every octave, or series of the eight regular sounds, contains five tones and two semitones. To prevent confusion it must be always remembered, that a note and a tone are distinct things, the former is a simple sound, the latter the distance between two sounds. We have in a previous part of this Essay shown that the octave consists of two tetrachords, or series consisting of four sounds each; practically this was sufficiently near the truth, but the theory of sounds does not admit strict mathematical equality between these fourths, as respects the places of the tones whereof they are composed, as will be hereafter noticed; in this part we shall still consider that the fourths, consisting of the sounds G, A, B, C and C, D, E, F are equal, each containing two tones and a semitone, and therefore that a tune formed by one of them will be equal or the same in a different pitch to a tune formed by the other, thus,



The two fourths taken in succession then forming a scale, whereof the principal sound is C, from which it begins, and to which it finally ascends in degrees continuously placed, give the name of *key note* to that principal sound; and it must be further remarked, that the effect of the octave upon the ear depends upon the semitones being placed in a certain position, namely, between the third and fourth and the seventh and eighth notes of the series,



for in no other way will the ear suffer itself to be brought back to the key note in the ascending or descending scales. The great Bacon says, "after every three whole notes Nature requireth for all harmonical use, one half note to be interposed." Referring this scale to keyed instruments, such as the organ or piano-forte, it is called the natural scale, because the keys employed in it are the long white keys, in distinction from the black or short keys, which when employed involve some peculiarities, and give their use the name of the *chromatic scale*, or one, as its name imports, of a different colour, but not with relation to the difference of black and white in the keys of a finger-board.

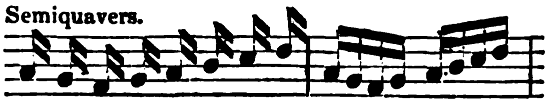
The time or measure of notation.

The period of time assigned to each note, or, in other words, its absolute duration, is known by its form, taking a unit to represent any character, all the rest must bear a strict proportion to it. Though the character known by the name of the large is now no longer in use, it was formerly often employed in Ecclesiastical Music; it is not, however, so convenient a measure as the semibreve, which is found in all modern arrangements, and which we shall therefore use in the following Table.

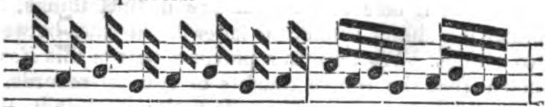
8	A Large .	𝆶	contains in time	2 Longs .	𝆷 𝆷
4	A Long .	𝆷	. . .	2 Breves .	𝅜 𝅜
2	A Breve .	𝅜	. . .	2 Semibreves .	𝅝 𝅝
1	A Semibreve .	𝅝	. . .	2 Minims .	𝅗𝅥 𝅗𝅥
$\frac{1}{2}$	A Minim .	𝅗𝅥	. . .	2 Crotchets .	𝅘𝅥 𝅘𝅥
$\frac{1}{4}$	A Crotchet .	𝅘𝅥	. . .	2 Quavers .	𝅘𝅥𝅮 𝅘𝅥𝅮
$\frac{1}{8}$	A Quaver .	𝅘𝅥𝅮	. . .	2 Semiquavers .	𝅘𝅥𝅯 𝅘𝅥𝅯
$\frac{1}{16}$	A Semiquaver .	𝅘𝅥𝅯	. . .	2 Demisemiquavers	𝅘𝅥𝅰 𝅘𝅥𝅰
$\frac{1}{32}$	A Demisemiquaver	𝅘𝅥𝅰			

The lower denominations of these notes from the quaver are often grouped together, instead of being detached, a practice not only convenient in writing, but assistant to the eye, as under.

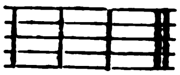
Semiquavers.



Demisemiquavers.



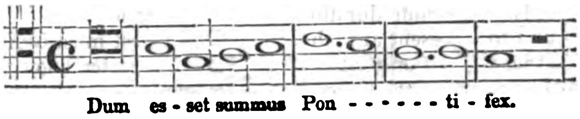
The same practice also may be, and is adopted with quavers. If a dot be added to the right hand of a note, it increases the value of such note exactly one half of its duration without it. The measure of the time or duration of a note in performance, is by long habit familiar to the Musician, and he generally regulates it by *beating time*, that is, by the raising and falling of his hand or foot, in some pieces slower, in others quicker, according to the subject of the Music to be sung or played. The ordinary common measure is a second, or sixtieth part of a minute, which is nearly the space between the beats of the pulse and the heart, the systole or contraction answering to the elevation of the hand and its diastole, or dilatation, to the letting it fall. This measure usually takes up the space that a pendulum thirty inches in length employs in making a swing or vibration. An instrument, called a Metronome, has been invented within the last few years for measuring the length of a note mechanically; it consists of a pendulum with a weight shifting on the rod, so as to increase or diminish the vibrations in number, according to a graduated scale on it.

The measures into which every Musical piece is divided are called *bars*, which are the vertical lines separating the spaces in the staff, thus, 

The single lines taking merely the name of bars, and the two thick lines at the end being called a *double bar*, which is placed at the end of a strain.

Common time.

The signs or characters by which the time of notes are represented, are but of two sorts, namely, *common time* and *triple time;* all have their origin in these two. Common, or double time, is of two species; first, that in which every bar, or measure, equals a semibreve in duration, or its value in any combination of notes of less quantity; the second, where a minim, or its value in less notes, takes up the time of a bar. The movements of this kind of measure are various, and there are three ordinary distinctions of them, the first whereof is slow, and is marked with a C, or semicircle, thus, C at the beginning of the piece placed after the clef. The second is also a semicircle, but has a bar drawn through it thus, ₵ is rather quicker, and is often called *alla breve*, because it was formerly written with one breve in a measure thus,



Dum es - set summus Pon - - - - - - ti - fex.

The third sort of movement is very quick, and is marked thus, Ↄ this, however, is now rarely used. The other characters of common duple time are 2 or $\frac{2}{4}$ or $\frac{4}{8}$ signifying the measure of two crotchets to be equal to two notes, whereof four make a semibreve.

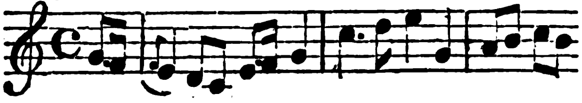
Triple time.

Triple time is of many species: it takes its name from the whole or half the bars being divisible into three parts, which are beat accordingly, the first down, the second with the return of the hand, and the last with the hand quite up; which motions the Italians express by the words *ondeggiare la mano*. It is always represented by figures placed after the clef, at the beginning of the staff, the lower one, or denominator, showing into how many parts, or notes, the semibreve is divided, and the upper one, or numerator, how many of such parts, or notes, are contained in a bar, thus $\frac{3}{2}$ signifies three minims in a bar; 2, the denominator, being the division of a semibreve or 2 minims; so $\frac{3}{4}$ signifies three crotchets in a bar; $\frac{3}{8}$ three quavers; $\frac{6}{4}$ six crotchets; $\frac{6}{8}$ six quavers; $\frac{9}{8}$ nine quavers; $\frac{9}{16}$ nine semiquavers; $\frac{12}{8}$ twelve quavers. Other species of compound triple time are to be found in some authors, but the reader, on meeting with them, and using the explanation above given, will find no difficulty in their solution.

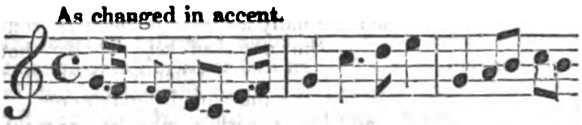
ent.

Every bar or measure is divided into *accented* and *unaccented* parts; the first are the principal, and on them the spirit and effect of the Music is mainly dependent. The beginning and middle, or the beginning of the first half of the bar, and the beginning of the latter half of it, in common time, and the beginning or first of three notes in triple time are always the accented parts of the bar. As the character of the melody is quite changed by altering the accented parts of its bars, it frequently becomes necessary to begin a movement with only part of a measure; of this, in the following song, *The Lass of Patie's Mill*, this is sufficiently manifest.

As written.



As changed in accent.

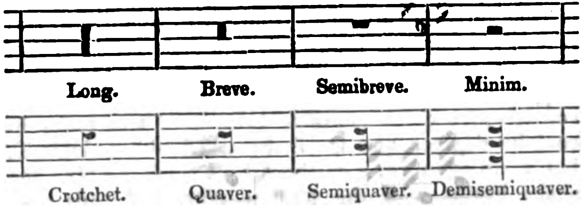


Syncopation.

When a striking or breaking of time takes place in a bar it is called *syncopation*, but the term is more particularly used for connecting the last note of one bar with the first note of the following one, so that only one note is made of both of them. It is also used in the middle of a measure, likewise when a note of one part ends or terminates in the middle of a note of the other; this, however, is otherwise called *binding* or *ligature*. Syncopation is moreover used for a *driving note*, or when some shorter note at the beginning of a measure or half measure is followed by two, three, or more longer notes before any other occurs equal to that which occasioned the driving note to make the number even, as when an odd crotchet comes before two or three minims, or an odd quaver before two or more crotchets, &c.

Rests.

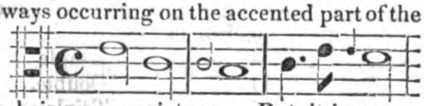
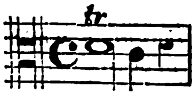
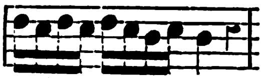
Rests are pauses or intervals of time in a movement during which the voice or sound intermits or pauses. They are used occasionally in melody for the sake of variety or expression, but their great use is in harmony or compositions of several parts, in which pleasure is created by hearing one part move on while another pauses, and so on interchangeably. Rests are either for a bar, more than a bar, or only a part of a bar. When the rest is for a part of a bar it is expressed by a certain character corresponding to the quantity of time to be intermitted, as to a minim, crotchet, quaver, &c., and is accordingly called a minim, crotchet, or quaver rest, &c. and when these are used on a line or space, the part is silent for the duration of a minim, crotchet, or quaver respectively, or for such other quantity of time as may be marked. We subjoin the different characters of the several rests.

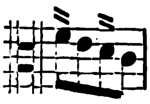
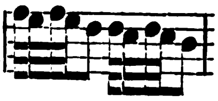


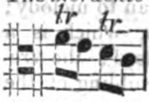
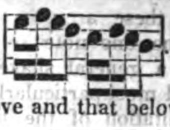
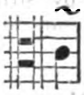
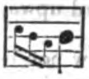
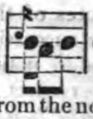
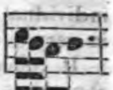
Sharps, flats, &c.

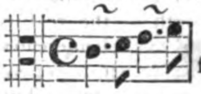
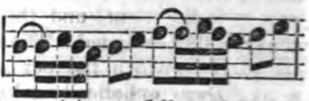
In performance, in order to give due expression to the Music, great attention should be paid to the observance of these signs. The natural scale of Music, if limited to fixed sounds, and adjusted to an instrument, would render the instrument defective in many points and peculiarly, inasmuch as we should be able to proceed only by one particular order of degrees, and thence could not find any interval required from any given note upwards or downwards. So that a melody might be so contrived as that if it began on a certain note all the intervals might be truly found on the instrument, yet if it began on any other note the same melody could not proceed because of the different proportions of the intervals. To remedy this defect, Musicians have had recourse to the following expedient, namely, to divide the octave into thirteen notes, inclusive of the extremes, that is to make the scale proceed by twelve degrees, by which means the instrument is rendered so perfect that there is little reason to complain. This system or scale for instruments whose sounds are fixed, is effected by inserting between the extremes of every tone of the natural scale a sound or note which divides it into two semitones. When we come hereafter to speak on temperament, it will be seen that the semitones are not an exact mean between the tones themselves, but in keyed instruments they may be considered as such for our present purpose. In order to preserve the diatonic series distinct, the notes inserted as above mentioned either take the name of the natural note next below, with this character ♯, called a ***sharp***, or that of the natural note next above it, with this character ♭, called a ***flat***. Thus, in the semitonic series of an organ or pianoforte, the same key will be indicated by D♯, or E♭, and thereon the white or lowermost range of keys represent the natural or diatonic notes, and the black, or those behind, the artificial ones, or flats and sharps. There is another character which belongs to this place; if a note has been elevated by a sharp, or depressed by a flat, the natural ♮ prefixed to it restores it to its original place in the scale, or if flats or sharps have been placed at the beginning of the staves or lines, or in spaces which affect all the notes placed on or between them, the natural contradicts them, as may be required. Besides these, two other characters are used, namely, the double sharp × and the double flat ♭♭, which prefixed to notes, raise or depress them respectively two semitones.

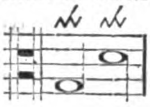
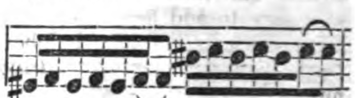
Graces.

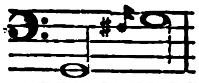
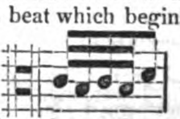
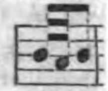
The chief graces used in melody consist of the ***appoggiatura***, the ***shake***, the ***turn***, the ***beat***, with the ***mordente, beat, slide***, and ***spring***, used especially by the Germans. The ornaments of harmony are the *arpeggio*, *tremando*, &c. The *appoggiatura* is a small note placed before a large one, from which it borrows half the duration, always occurring on the accented part of the measure thus,  the small notes being appoggiaturas. But it is necessary to remark, that the appoggiatura, which in the example proceeds from the degree above that on which it leans, may equally come from the degree below, and that in the first way it has grace, in the second more of languor and affection. The appoggiatura is sometimes only a quarter of the note it precedes. The ***shake*** consists of a quick alternate beating of two notes in conjoint degrees, and is often marked with a single T, but more often ***tr***, sometimes by a small ***t*** only; the shake begins with the highest note, and ends with the lowest, after a turn from the note below thus,  performed 

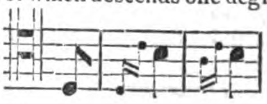
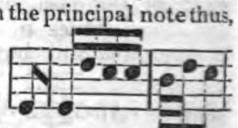
A series of continued shakes, ascending or descending, is called by the Italians *una catena di trilli*. The ***passing shake*** of Germany is expressed by the mark ≈ written over the note thus,  performed 

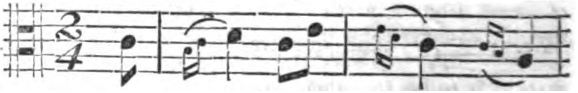
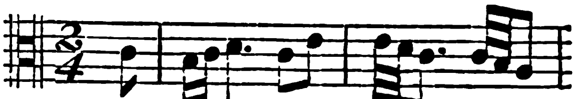
The *mordente* of the Italian School is similarly employed,  performed  The *turn* is made by using the note above and that below in the following manner,  or  performed  or 

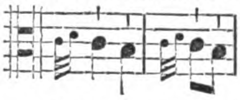
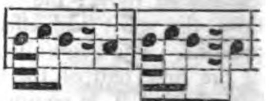
The *inverted turn*, marked ∽, turns from the note below that marked instead of above it. The *turn on dotted notes* is in very frequent use, and is written in the following manner,  performed 

The *beat* is an inverted shake, and is not followed by the turn, as in the case of the shake. It is used generally from the semitone below, hence that note, if necessary, must be accidentally sharpened for the beat, thus written,  performed 

The *half beat* is rarely used, except in the bass, and almost instantaneously with the principal note then immediately quitted, as  It is very similar to the *acciaccatura* of the Italians. The *German mordente* is a beat which begins with the note itself, and is long thus,  or short thus, 

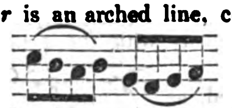
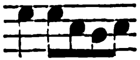
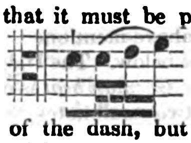
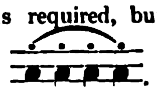
Its difference from the mordente above-mentioned, consists in its being made with the degree below. The Italians always use the degree above. The *German beat* is nothing more than a skip, consisting of two small notes, the latter of which descends one degree upon the principal note thus,  performed 

This grace has been called a *double appoggiatura*. The *slide*, which is a German grace, is composed of two small notes moving by degrees, and is thus written,  performed 

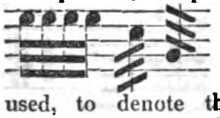
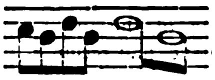
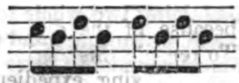
The *German spring* consists of two small notes, somewhat similar to the Italian mordente, but extremely distinct, thus  performed 

All the graces are subject to alteration by flats, sharps, or naturals, but the composer's duty is to mark them in that case as he wishes them to be executed. Under the head of notation, it is proper to notice some of the graces which more properly belong to harmony than to melody; the principal of these are, the *tremolo*, which is a reiteration of some one note of the chord; the *tremando*, which is a general shake or trembling of the whole chord; and most particularly the *arpeggio*, which is effected in imitation of the harp by striking the individual notes of the chord upwards and downwards in very quick succession.

Other Musical characters.

It remains to notice a few not unimportant Musical characters, as respect the expression of Music. The first is the *pause*, 𝄐 which, placed over a note, signifies that the duration of its sound is to be prolonged beyond its regular length; and if placed over a rest, that the part is to be silent, and that the length of the rest is considerably extended. The *repeat*, 𝄋, which indicates the place to which the performer must return to repeat a passage, emphatically called in Italian *il segno*. The *direct*, ʍ employed at the end of a staff to direct the performer's attention to the succeeding note on the line or space whereon it is always placed. The single and double bar have already been explained; it is only necessary to add here, that every measure, as we have seen, contains a certain number of notes, marked by single bars, and that every *strain* consists of a certain number of measures, which are terminated by double bars. The *slur* is an arched line, connecting a group of notes thus,  to signify that the group is to be played as smoothly and conjointly as possible. It differs from the *tye*, which is an arch merely uniting two notes on the same degree, thus,  The *dash* is a small vertical line placed over a note, to show that it must be performed shortly and distinctly, thus,  By some the *point* is used instead of the dash, but the former is chiefly used to distinguish notes from which an intermediate effect between the slur and the dash is required, but still uniting both, it is thus marked, . The *crescendo*, or gradual increase of the sound, is marked thus, 𝆒. The *diminuendo*, or gradual decrease of sound from loud to soft, is marked contrariwise thus, 𝆓. The junction of these two characters 𝆒𝆓 shows the first part of the note or passage is to be soft, then to swell in force, and afterwards to return to soft. The *rinforzando* 𝆓𝆒 is the reverse of the preceding.

bbrevia-ons.

Abbreviations are used in Music for the sake of saving time to the copyist. Thus a line drawn over or under a semibreve, or through the tail of a minim or crotchet, divides it into quavers, a double stroke into semiquavers, a triple stroke into demisemiquavers, thus,  and the Italian word *segue* is often used, to denote that the notes following are to be performed as the preceding ones are marked. Another sort of abbreviation is that in which the tails of minims are connected like those of quavers, thus  performed  There are other abbreviations which it is not necessary to enlarge upon in this place.

Melody

Melody.

Is the arrangement and disposition of different sounds in succession in a single part, and is produced by a single voice, or instrument, and is thereby distinguished from, though often in common speech confounded with harmony, which is the union of two or more consonant contemporaneous sounds successively. Though the term *melody* is generally applied to the air of a piece, yet it is to be recollected that the more melody is contrived in the other parts the better will be the composition. Melodies, as will be hereafter shown in respect of harmonies, are composed of the Musical or harmonical intervals, as the second, third, fourth, fifth, sixth, and octave; and as the octaves of each of these are but repetitions of the same sounds, whatever is said of all or any of these sounds the same may be said of their octaves. Melody is a progression therefore of sounds by skips or by degrees, or by a combination of both. Whether by skip or degree, the distance from the note last left is called an interval, and takes its name in proportion to its distance. De Momigny divides melody into two species, *univocal* and *polyvocal*. The former is that confined to a single note in each chord, the latter when it produces the effect of more than one voice. We have not space to insert his ingenious explanation, but must refer such of our readers as wish to pursue this branch of the subject to his Article *Mélodie*, in the *Encyc. Méthod.* 1818.

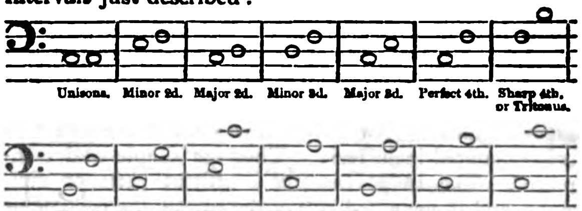
Intervals.

The names of the intervals show the number of degrees contained between the two sounds, the extremes being counted inclusively. They are simple and compound. The *simple interval* is without parts or divisions, and is contained within the octave, the *compound interval* consists of several lesser intervals. Those in the upper line in the following Table are simple intervals, the other three lines are compound, that is doubled, tripled, quadrupled, &c.

1	2	3	4	5	6	7	Simple.	
8	9	10	11	12	13	14	Double.	Compound intervals.
15	16	17	18	19	20	21	Triple.	
22	23	24	25	26	27	28	Quadruple.	
29, &c.								

In the above Table it will be seen, that the compound interval is but a repetition of a simple interval an octave above, thus the sixteenth is a reduplication of the second and the twenty-seventh of the sixth; or, in other words, a compound interval is such whose terms are in practice, either taken in immediate succession, or when the sound is made to rise and fall from the one to the other by touching some intermediate degrees, so that the whole is composed of all the intervals from one extreme to the other.

The fourteen diatonic intervals are *the unison*, which, though consisting of two sounds equal in degree of time, is still reckoned as an interval when considered in harmony. The *minor second*, sometimes denominated the *flat second*, is the interval formed by two sounds at the distance of a diatonic semitone, as from B to C, and E to F. It is also necessarily found in the other scales, as will hereafter be seen. The *major second*, consisting of a whole tone. The *minor third*, which contains a whole tone and a diatonic semitone. The *major third* containing two whole tones. The *perfect fourth* composed of two tones and a diatonic semitone. The *sharp fourth* containing three whole tones, and thence called by the Ancients the *Tritonus*. The *flat fifth* contains two tones and two semitones, but not three whole tones, it may be rather said to consist of two minor thirds. The *perfect fifth*, which contains three tones and one semitone, or a major and minor third. The *minor sixth*, consisting of three tones and two semitones, also divisible into six semitones, and joined to a major third completing the octave. The *major sixth*, which contains four tones and one semitone, or nine semitones. The *minor seventh*, containing four tones and two semitones, divisible also into a fifth and minor third, or into ten semitones. The *major seventh*, called also the *sharp seventh*, composed of five tones and one semitone, also divisible into a fifth and major third, or into eleven semitones. Lastly, the *octave*, which is composed of eight degrees. The octave then consists of thirteen sounds, and, as it has only twelve intervals, it must therefore be recollected, that the fourteen diatonic intervals above described arise from counting the unison as one of them, and by the distinction between the sharp fourth and flat fifth, though upon keyed instruments the same key expresses them both. It will appear thence, as we have before mentioned, that the seven notes of the scale are capable of forming seven species of octaves according to the places of the natural semitones. We subjoin for more distinct comprehension a synopsis of the intervals just described:



Inversion.

Inversion is caused by placing the lower note of an interval an octave higher, or the converse, thus a second is converted into a seventh, a third into a sixth, a fourth into a fifth. By this process the major are converted into minor intervals, and the contrary. The sharp fourth is turned into a flat fifth, and the unison becomes an octave.

Major and minor modes.

In speaking of the Ecclesiastical tones, we have adverted to the authentic and plagal modes, and have explained that the authentic has its melody between the key note and its octave, whilst the plagal is confined between the fifth of the key, and its octave or twelfth. A consideration of this may have already led the reader to reflect upon the major and minor modes of Music now to be mentioned. It is usual to denominate the scale by the species of third which it carries, either major or minor; this, in truth, gives it the name of the major or minor mode; and Malcolm, very judiciously, to prevent confusion, and for greater exactness in the nomenclature, says, that an octave with its natural and essential degrees is a mode; but with respect to its place in the scale of Music, that is, its pitch of tune, it is a key, though that name be peculiarly applied to the fundamental. Whence it follows, that the same mode may be with different keys, that is, an octave of sounds may be raised in the same order and kind of degrees, which makes the same mode, and yet be begun higher or lower with respect to the whole, which will make different keys; and, on the contrary, that the same key may be with different modes, that is to say, that the extremes of two octaves may be in the same degree of tune, and the division of them be different.

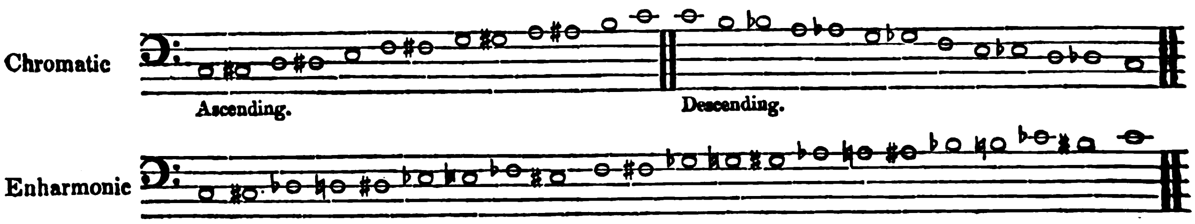
Consonances and dissonances.

Under the head of Melody we do not think consonant and dissonant intervals properly find place, they may be more fittingly considered under Harmony, to which the reader is referred. We shall here merely state, that what are called the consonant intervals as most agreeable to the ear, are the octave, fourth, fifth, the two thirds, and the two sixths, that seconds and sevenths are always considered dissonant, and that the fourth and fifth are only considered consonant when perfect.

Chromatic and Enharmonic Melodies.

Chromatic and enharmonic melody.

The preceding observations have been applicable to the melody arising from the use of a diatonic scale. We shall now consider the other scales. The chromatic scale has its etymology in the Greek word χρῶμα, *colour*, according to the authority of some, because the Greeks distinguished it by differently coloured characters; according to others because the chromatic genus was a mean between the diatonic and enharmonic genera as colour is a mean between black and white; but according to others, because this genus varies and embellishes the diatonic by its semitones, producing in Music the same species of variety that colours do in a Picture. As in the diatonic genus the tone is its characteristic, so in the chromatic the semitone is the distinguishing element. Thus a scale formed of semitones inserted between all the natural tones is called a chromatic scale, and the melodies used upon it are chromatic melodies. The enharmonic scale is formed by uniting the ascending with the descending scale of the chromatic genus, by the use of an interval created between the sharpened note of the preceding, and the flattened note of the succeeding one. It consequently contains intervals smaller than the semitone. These, though not exactly equal to half a semitone, are, from their approximation to that quantity, called Dieses, or Quarter Tones. These matters will be better understood by the inspection of the scales which we here therefore append.

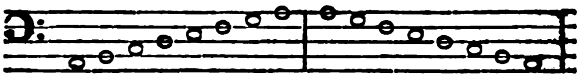


In the enharmonic scale here we have inserted the intervals F♭ and E♯, also C♭ and B♯, but they do not properly belong to the scale as their distance is smaller than a quarter tone. Rightly to understand this, it must be known that in the theory of harmonics, the interval of a tone throughout the diatonic scale is not equal in every part; for instance, the tone between the fourth and fifth is imaginably divided into nine parts, called commas, whereas that between the fifth and sixth of the major scale consists of only eight commas. So the diatonic semitone consists of five commas, and the chromatic semitone of three or four, according to the magnitude of the tone. There is an interval, also, called hyperoche, which by nice calculation is found to be a comma and a half.

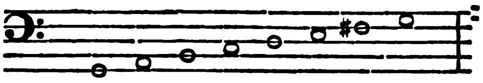
Scales or Keys.

cales or eys.

It will now easily occur to the reader, that there may be many diatonic scales formed out of an octave of sounds, the notes in each bearing certain relations to some principal note from which they are derived, and on which they depend; this is called the *key note* or *tonic*. The guides to point out this key note will be the places which the semitones hold in the scale. In the diatonic scale it has been seen that these fall between E F and B C in the major mode. It has been noticed, that in the minor mode the two diatonic semitones are between the second and third, and between the fifth and sixth degrees. The only series of this kind among the natural notes is the key of A as under, and which may be taken as a specimen of all the minor scales.

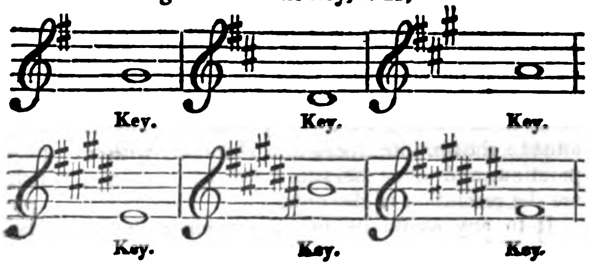


Now it is evident that in major modes, if we change the tonic or key note from the diatonic scale of E, and begin upon the G above, as a new tonic, or key note, in order to preserve the relative intervals of semitones in the scale it will be necessary to sharpen the seventh F, thus,

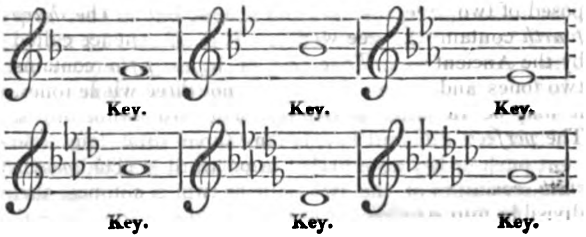


So if D be taken as the tonic or key note, we shall not only have to sharpen the F, but C then becomes the seventh, and that also must be sharpened, thus bringing two sharps, till having gone through the scale with the fresh creation of sharpened notes, we shall have arrived at the key of F sharp with six sharps. Instead of being marked as they occur, which in writing would be an inconvenient practice, it is usual to place them at the beginning of a staff immediately after the clef, and this is called the signature of the key, thus,

tures.



The same process takes place with keys bearing flats, where the introduction of a flat must be on the seventh of the original key, in order to preserve the regular proportions of the different intervals of the scale, and from this rule all the following signatures of flats are formed:

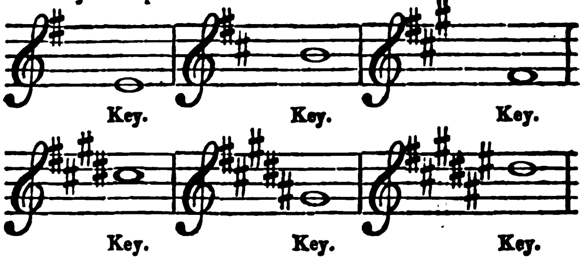


It is necessary to observe, that in performing on keyed instruments, such notes as E, the sixth flat in the last signature, B natural is used instead of it owing to the imperfection of dividing the instrument so with G♭, &c. &c.

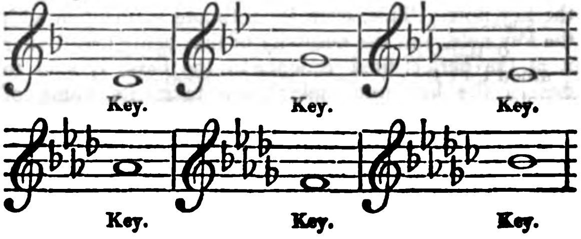
The scale of the minor mode, which differs as we have seen in the place of its semitones, varies also from it by the ascending and descending scales being different, for when the seventh of the scale ascends to the octave, or eighth, it must be sharp as the leading note to the tonic. This sharp is always, however, omitted in the signatures of the minor keys, but marked accidentally in the melody when required. But with this sharp seventh alone, a very harsh chromatic interval, called the extreme sharp second, occurs between F♮ and G♯ in the natural scale, and to avoid this the sixth also is made sharp, and thus the accidental scale of the minor has two notes altered from the signature, but in the descending scale the leading note being depressed to fall on the sixth the signature requires no accidentals.

The signatures of the minor modes are the same as those of the major proceeding either by sharps or flats, thus,

By Sharps.



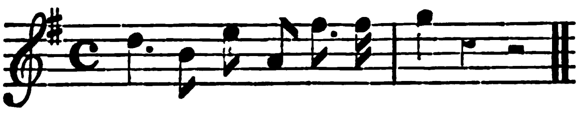
By Flats.



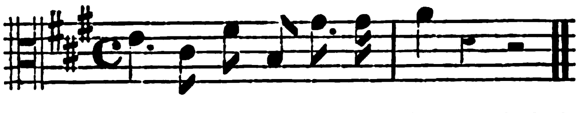
The major and minor scales bearing similar signatures are called relative, thus of the major key of D, the minor key of B is said to be its relative minor, in which case the tonic of the minor mode is found to be the sixth note ascending of the major scale bearing the signature, and these tonics will always be found one degree below the last sharp of the signature, and in signatures with flats always the third degree above the last flat.

Transposition.

Transposition is the changing any melody into a key or clef different from that in which it was originally composed or stands written. There are two sorts of transposition, the first with regard to the clef, and the second with regard to the key. The first consists in changing the places of the notes among the lines and spaces, but so that every note be set to the same letter. It is effected by moving the same clef to another line, or by using another clef, but with a signature that places the tones and semitones in the same order as before. The last, or setting the Music in a different key, is the change of it to a different pitch or key note to that in which it is noted, so that the semitones of the two fourths which compose them may be found by means of flats or sharps, exactly in the same range or proportion to each other as before transposition. Thus,



Transposed a 7th lower.



Modulation. When a melody moves out of the key in which it commences, and the original scale is altered by new sharps or flats, the change is called *modulation*. Under this term is comprehended the regular progression of the several parts, through the sounds in the harmony of a particular key, as also the proceeding naturally from one key to another, this will be hereafter noticed under the following head Harmony. We will merely observe here, that each major scale is naturally connected with two others, which are called its attendant scales, one a fifth above it, which adds a sharp to the signature, the other a fifth below it, which adds a flat to the signature. So also every minor scale has its attendant scales.

Characteristic notes. There are certain names given to notes in the scale as peculiarly marking their character. It is not our intention to use them in the following pages, we however think it right that they should be known to and understood by the reader.

First, the *tonic*, or key note, which is the chief sound in a melody, and upon which, either in the chief melody or in the base, all melodies terminate. Its octaves, both above and below, take the same name.

Secondly, the *dominant*, which is a perfect fifth above the key note. This, from its intimate connection with the key note, and the necessity of that being heard after it at the perfect final cadence in the bass, is said to govern the key note, and thence takes its name of dominant.

Thirdly, the *subdominant*, or fifth below the key note, or the fourth above it in the ascending scale. It takes its name from its being also in some measure a governing note, inasmuch as the tonic requires to be heard after it in the plagal cadence.

Fourthly, the *leading note*, or sharp seventh, which the Germans call the subsemitone of the mode. It is always a major third above the dominant, and, consequently, as we have before observed, requires an accidental sharp or natural in the minor scale, when it occurs.

Fifthly, the *mediant*, which, as its name imports, is the middle note between the tonic and dominant in ascending, hence it varies as the scale is major or minor, in short, with its learned name, it is nothing more than a major or minor third.

Sixthly, the *submediant*, which, as its name also imports, is the middle note between the tonic and subdominant in the descending scale, or, in other words, the major sixth in the major scale, and in the minor scale is called the minor sixth.

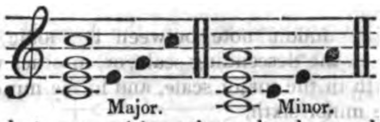
Seventhly, the *supertonic*, or second above the key note, so called by Dr. Callcott, in his excellent *Musical Grammar*, to which we acknowledge ourselves under very considerable obligations; he has so translated it from the French *sutonique*. The reader may very advantageously refer to this Grammar for some well-chosen examples of melodies in which these seven principal notes in the scale occur.

We here close our remarks on Melody by observing that in early Music the signatures of sharp keys are usually given with a sharp less than would indicate the key in which they are written; for instance, in the key of A, the third ♯ which occurs on G is generally inserted as an accidental; so in the flat keys, the signature of one flat will usually be found to indicate the key of B♭ major or G minor. The key of E♭ major has rarely a signature of more than two flats, the accidentals then being always marked.

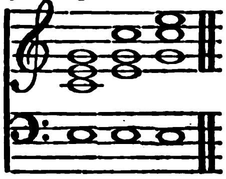
Harmony

Definitions. Consists in the contemporaneous production of two or more sounds conformable to certain rules of Art. To understand this branch of the subject the reader must refer back to a former page, (722,) in which all the different intervals occurring in the scale have been placed before him, as without the clearest understanding and recollection of those intervals his comprehension of what is now to follow will be hopeless. A *concord* is the relation of two sounds which is agreeable to the ear; if they are in such relation, with such a difference in pitch that being sounded together the mixture affects the ear with pleasure, that relation is called concord. Those sounds which make an agreeable compound in consonance, will also be pleasing in succession. Concord is included in the term Harmony, but it is more properly applied to the agreeable effect of *two* sounds in consonance, whereas Harmony expresses the agreement of a greater number of sounds than two. A *discord* is the relation of two sounds which are always of themselves disagreeable, whether applied in succession or consonance. If two sounds are in such a relation of tune or pitch as that being contemporaneously sounded they make a mixture disagreeable to the ear, that is a discord, in contradistinction to the two agreeable sounds, which are called a concord. As concords are denominated harmonical intervals, so may discords be termed unharmonical intervals. The Harmony of discords is that wherein the discords are used as the solid and substantial part of the Harmony. By the due interposition of a discord, the succeeding concords receive an additional lustre from the contrast. They are always, as will hereafter be shown, introduced into Harmony with due preparation, and must be succeeded by concords, which are the resolution of discords.

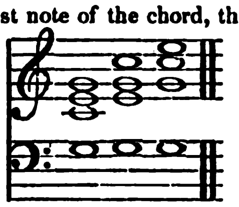
If to any sound its major or minor third and its perfect fifth be added, the arrangement is called a *common chord*, in which it is necessary to express the minor third, if that be used, otherwise it is usually taken to be the common chord with the major third, to which, if the octave to the sound be added, we have a combination of four sounds in the harmony, thus,



Now in whatever positions these chords are placed, provided the C or A remain the lowest notes, the chord still bears the name of the common chord of C and A respectively. The other notes remaining the same, if the position of the lowest note be altered, the name of the chord immediately changes, thus,

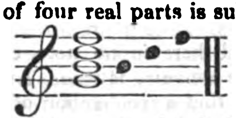


If E of the common chord of C be used as the lowest or bass note, the chord is then called a sixth, because the key note is then a sixth interval from the bass note, and that sixth, it will be seen, has above it for its accompaniment a minor third from E to G. Now, if G be used as the lowest note of the chord, thus,

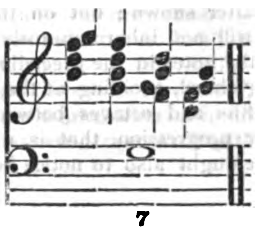


we have the key note a fourth above the bass, and the chord is that called the fourth, and is accompanied, as will be seen, by the sixth. These two chords, then, the sixth and the fourth, are inversions of the common chord, and have the same note C as their expressed or understood bass, which is the *fundamental bass*, or that on which they are constructed. The same arrangement will also hold in respect of common chords with minor thirds. The first or common chord is expressed shortly by figures placed below the notes in the bass $\begin{smallmatrix}3\\5\\8\end{smallmatrix}\ \begin{smallmatrix}5\\8\\3\end{smallmatrix}$ or $\begin{smallmatrix}8\\3\\5\end{smallmatrix}$, but to the common chord these are often omitted. The second, or chord of the sixth, is merely figured with a 6, and the third, or chord of the fourth, is denoted by the figures $\begin{smallmatrix}6\\4\end{smallmatrix}$.

The most simple of the discords is called the minor seventh, or by some the dominant seventh; the latter of which appellations is given to it because it only occurs on the fifth or dominant of the key, and requires the part on which it is heard always to descend one degree. Its full accompaniment of four real parts is subjoined.

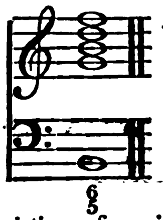


As in the case of the common chord, either of these four notes may be the bass or bottom note of the chord; yet, as with C in the common chord we have just left, the fundamental bass note of it will be G, B will be the third, D a perfect fifth, and F a minor seventh; thus



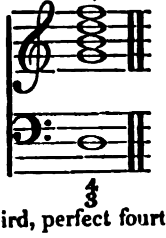
and in each case it would bear the figure 7, or mark of the seventh placed below it in the example. It is sometimes also figured $\begin{smallmatrix}8\\5\\7\\8\end{smallmatrix}\ \begin{smallmatrix}7\\5\\3\end{smallmatrix}\ \begin{smallmatrix}5\\3\\7\end{smallmatrix}\ \begin{smallmatrix}8\\7\\5\end{smallmatrix}$, these positions containing the tenth, twelfth, and fourteenth of the root when the octave is subtracted.

If B be now substituted as the bass note, a chord is obtained,



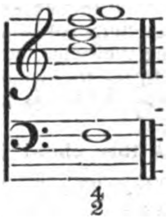
by the inversion consisting of a minor third, an imperfect (flat or false) fifth, and a minor sixth, and this is figured, as in the example, $\begin{smallmatrix}6\\5\end{smallmatrix}$.

If D be taken for the base, the chord becomes



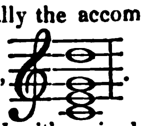
one of the minor third, perfect fourth, and major sixth, and it is figured $\begin{smallmatrix}4\\3\end{smallmatrix}$, as in the example.

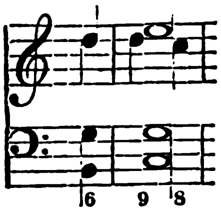
If F be used for the bass, it is then changed into a chord, consisting of a major second, sharp fourth, and major sixth, and is figured $\begin{smallmatrix}4\\2\end{smallmatrix}$, thus,



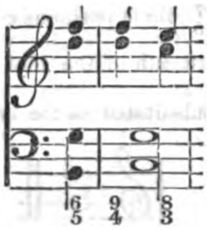
Hence the three last chords being the offspring of the seventh, are, with propriety, termed derivatives of the minor seventh, when accompanied by a major third and perfect fifth. By some persons the three last chords are called a syncopated fifth, a syncopated third, and a syncopated second respectively.

The ninth.

Hitherto we have confined ourselves to the consideration of chords within the compass of the octave, we now proceed to the discord called the ninth, which has generally the accompaniment of a third and fifth with it, thus,  To a composition in four parts, marked with a single 9, it is accompanied by the third and fifth, thus,



It is, however, often accompanied by a fourth and fifth, in which case it is marked with a double row of figures, thus,

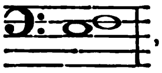
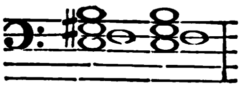
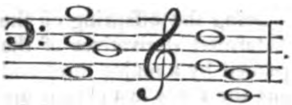
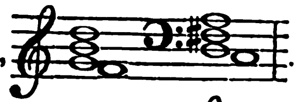
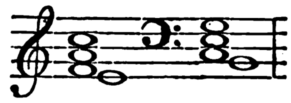


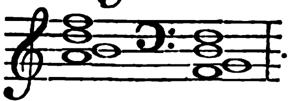
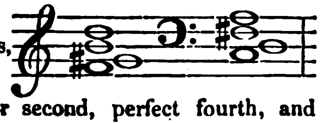
In three parts the fifth is omitted. The ninth, accompanied with the third and fifth, is, in truth, an appoggiatura continued in the place of the eighth. The chord of the ninth has two inversions, one of them figured with a seventh, the other figured with a fifth and sixth, the first on the third of the fundamental note, and the latter on the fifth of the fundamental note.

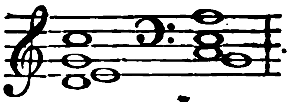
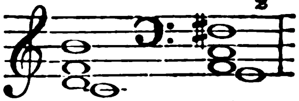
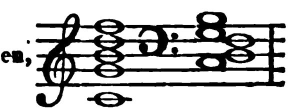
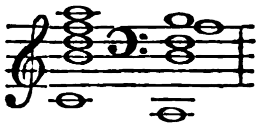
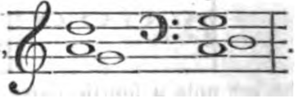
To the figures 4 and 6 are frequently added a dash, thus, $\not 4$, $\not 6$, which denotes them to be respectively a sharp fourth and a sharp sixth.

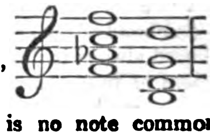
List of chords.

The above being the foundation of all knowledge of the different concords and discords employed in harmony, we shall proceed to enumerate the whole of the latter as they occur, from the second upwards, observing that they will, except those not direct, be found inversions of the seventh sharpened or flattened with major or minor thirds.

The second is marked with a 2, and written thus, , in which it is to be observed, that the lowest note is the discord. The chord marked $\begin{smallmatrix}5\\3\\2\end{smallmatrix}$ consists of four real parts, that is to say, it contains four real sounds without octaves or unisons: it is written thus, ; its use is to retard the $\begin{smallmatrix}6\\4\\3\end{smallmatrix}$ or $\begin{smallmatrix}6\\5\end{smallmatrix}$. When the third of this chord is sharpened, it indicates the minor mode. The chord $\begin{smallmatrix}5\\4\\2\end{smallmatrix}$ is thus written, . The chord of $\begin{smallmatrix}6\\4\\2\end{smallmatrix}$ is one of four real parts, three of which form a common chord above the bass, the note whereof is the discord; it is written thus, . The chord of $\begin{smallmatrix}6\\4\\\flat 2\end{smallmatrix}$ is expressed as follows, 

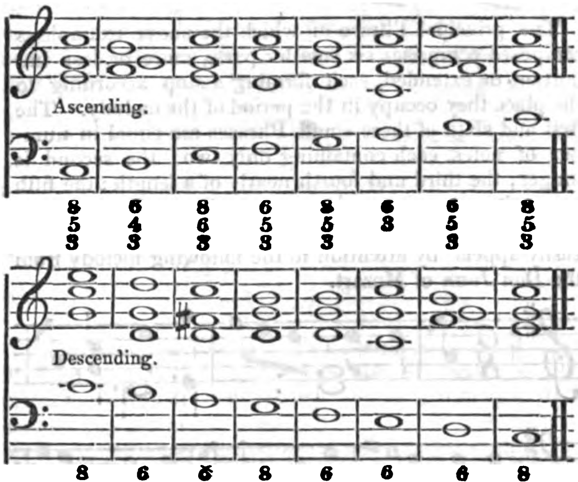
That of the $\begin{smallmatrix}6\\4\\2\end{smallmatrix}$ thus, . It is the imperfect common chord with a whole tone added below it. The $\begin{smallmatrix}6\\4\\\sharp 2\end{smallmatrix}$ is written thus, 

The chord of the major second, perfect fourth, and minor seventh, which is used to retard the common chord by an appoggiatura in the bass, is marked $\begin{smallmatrix}7\\4\\2\end{smallmatrix}$, and written . The chord of the sharp seventh is figured $\begin{smallmatrix}7\\4\\2\end{smallmatrix}$, and expressed in notes thus,  The following is by some called the chord of the eleventh, whereof the figure 4 is the representation, by others called the sharp seventh, but we consider the former the right name, $\begin{smallmatrix}7\\5\\4\\2\end{smallmatrix}$, and thus written,  The chord of the thirteenth, which in the figures is represented by a sixth, and may be either major or minor, is thus figured, $\begin{smallmatrix}7\\6\\4\\2\end{smallmatrix}$, and thus written,  In the chord of $\begin{smallmatrix}5\\2\end{smallmatrix}$ the fifth must be always perfect, the second either major or minor, and either may be doubled; it is written as follows, .

The above is as extended a view of the subject of *thorough* or *continued bass* (*basso continuo*) as our limits allow. From what has been shown at the commencement of this head, it will be collected that there are two species of bass, one imaginary, called the fundamental bass, to which all chords may be reduced by bringing them to the form of the perfect chord, or to that of the seventh; and the other the thorough, or continued, or figured bass, in which the real ground note of the chord is found by the aid of the figures, or by simple or continued inversion to reduce them to their elements. We have abstained, in this place, from all observation on the preparation and resolution of discords, because we have thought they better belonged to another branch of this Essay, where the reader will find sufficient to guide him in their use. Perhaps, however, we ought, in this place, to explain that *chords* are called *irrelative*, wherein a sound common to both does not occur in each, thus,  in which it will be perceived there is no note common to both; *relative* when the converse is true. And it may be here shortly observed, that a recollection of this fact will lead a young extempore player to results which will surprise him. He may, for instance, proceed from any chord to another, in which one of the sounds remains that has been employed in the chord previously struck: if discords occur, they must, of course, be prepared and resolved as hereafter shown; but on this he may rely, that one chord will not inharmoniously follow another, if only one of the notes in the preceding be preserved in the following chord, avoiding at the same time progressions of fifths and octaves between the extreme parts in similar progression, that is, moving both the same way. We ought also to notice here, as the more

Relative and irrelative chords.

proper place, that there is a progression of sounds called the harmony of the scale, which attends the ascent and descent of an octave, the general method of accompanying which is as follows:

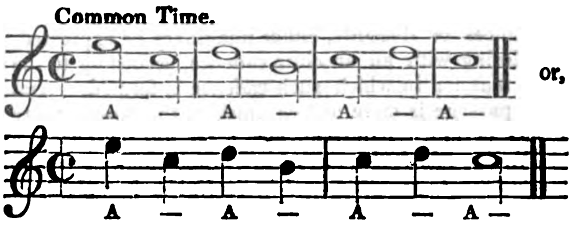


Rhythm.

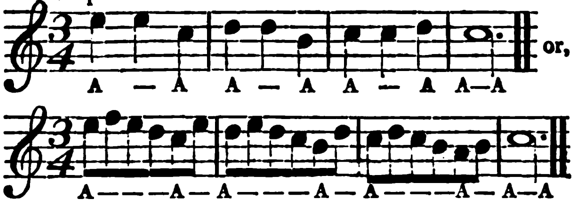
finition. In modern Music, Rhythm is the accommodation of the long and short notes to the syllables employed in the words, so that both the one and the other may be properly separated, and so perceptible to the ear, that what is sung may be distinctly understood. This is effected by disposing the melody or harmony, or even both, in respect of time or measure, so as to suit the words; or if the Music be instrumental, the expression only of the sentiment. The usual application of the term has been to denote the time or duration of many sounds heard in succession, whether such sounds be Musical, and produced by voices and instruments, or without a determinate tone, as the strokes of a hammer on an anvil, the beating a drum, the articulations of the human voice in common speech, in repeating poetry, or pronouncing an oration. In this place that species only is to be considered which concerns the regulation of melody; and there is great truth in the Greek saying, *Το παν παρα μουσικοις ὁ ῥυθμος*, even in application to modern Music. With the greatest and sincerest respect for the memory of Dr. Burney, and equally as much for an ingenious, learned, and most elegant composer, Dr. Callcott, whose Works have often soothed the cares of life in our earlier years, and still command our admiration, we must nevertheless consider their admission of what is called the Musical foot and Musical cæsura as included under the first division, *Accent* of Rhythm. It is doubtless true, that notes in groups may by their relative proportions of length to each other be made to correspond with iambi, spondees, trochees, pyrrhics, dactyls, anapæsts, and as many other poetical feet as were ever numbered. But we consider it more true, if truth can have comparison, that nine-tenths of the greatest Musicians the World ever saw, knew not even the names of the disyllabic or trisyllabic feet, a small portion only whereof we have enumerated; and if the authors above mentioned had not appeared to sanction such a principle, we should, notwithstanding the Germans, have used some other epithet than useless in characterising it. Indeed, Burney, in page 77 of his 1st volume, almost seems to think as we do, where he says, that "modern Music, by its division into equal bars, and its equal subdivision of these bars by notes of various lengths, unites to the pleasure which the ear is, by nature, formed to receive from a regular and even measure, all the variety and expression which the Ancients seemed to have aimed at by sudden and convulsive changes of time, and a continual conflict of jarring and irreconcilable rhythms." Our notion is, that Accent is the principal subdivision of Rhythm; secondly, the Phrase; and thirdly, the Section and Period. Such is the mode in which we intend to shape our consideration of this part of the subject.

Accent. *Accent* is the particular stress or emphasis laid on a certain part or parts of each bar according to the subdivision of the semibreve, minim, or other unit of comparison in the time marked at the beginning of the staff. We have before mentioned this subject incidentally as connected with notation, and we shall in the succeeding Part, as connected with composition, have to recur to it. Here we shall investigate, as far as our limits justify, the mode in which it is employed. Each bar or measure is divided into accented and unaccented parts, the former are the principal. In common time, the beginning and the middle, or the beginning of the first half of the bar and the beginning of the latter half are always the accented parts of the measure. In triple time, they are found in the beignning or first of three notes. So again in common time, the first and third crotchet of the bar are on the accented part of the measure. In triple time, where the notes go by threes, that which is in the middle of every three is unaccented, the first and last accented, but the accent of the first is so much stronger, that in many cases the last is performed as if it had no Accent. This great and predominant Accent and the want of it are accompanied by what is called the *thesis*, or depression of the hand, and *arsis*, or elevation of it, respectively. To give examples of what is meant, we subjoin the following, in which the accented parts are marked with an A, and the unaccented parts scored under.

Common Time.

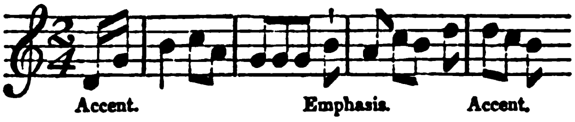


Triple Time.



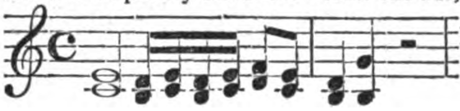
In the division of the bars or measures into groups of quavers, semiquavers, &c. though there be inferior accents to them, as well in common as in triple time, still the predominant accent of the measure is preserved, and must ultimately be referred to the primary division.

Emphasis. *Emphasis* is often obtained by deviating from the regular accent of the bar or measure, when the composer wishes to mark the weak part of it with more importance than the usually accented part. An admirable example of this has been selected by Dr. Callcott, in his *Musical Grammar*, from No. 3, Haydn's Symphonies: it is as follows:

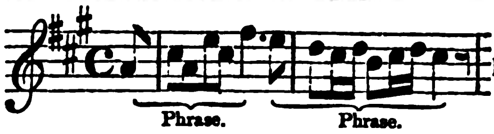


in which it will be observed, that in the first two bars the quavers are grouped according to the Accent, in the third contrary to the Accent, but according to the Emphasis required, and in the fourth the Accent is resumed. The same excellent authority says, that "in performing on the piano-forte a great difference seems to exist between them," (Accent and Emphasis,) "since Accent always requires *pressure* immediately after the note is struck, and Emphasis requires *force* at the very time of striking the note. Thus Accent may be used in the most piano passages, but Emphasis always supposes a certain degree of forte."

Phrase. An arrangement of notes either in melody or harmony, forming a passage more or less complete as its termination in cadence happens, is called a Musical Phrase; it generally consists of two bars, though in the older Writers it is frequently contained within one bar, thus,



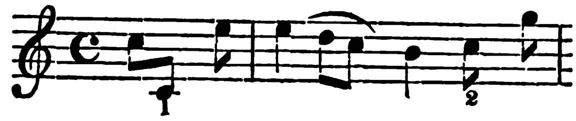
Beethoven, Op. 2.

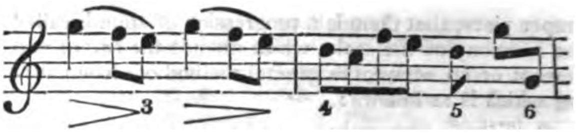


Handel.

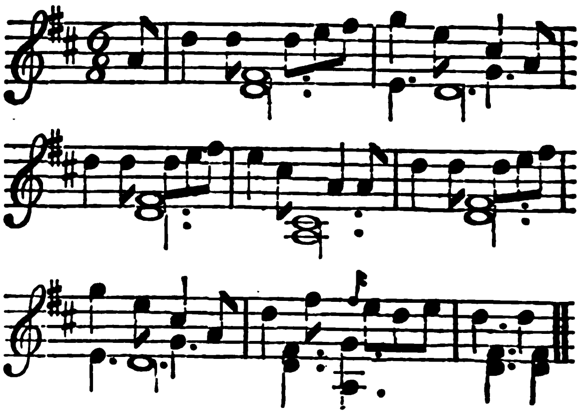
There are two sorts of Musical Phrases. In melody, the Phrase is formed by the air, that is to say, by a sequence of sounds so disposed that they form one whole, ultimately leading to their close upon some essential part of the mode in which they are written. In harmony, the Phrase is a sequence of chords connected by dissonances or discords, either imaginary or expressed, and closing with an absolute cadence, according to the usual manner in which such cadence is formed. And as the passage is more or less finished, the close is more or less perfect. Rousseau has, *C'est dans l'invention des Phrases Musicales, dans leurs proportions, dans leur entrelacement, que consistent les véritables beautés de la Musique. Un compositeur qui ponctue et phrase bien, est un homme d'esprit: un chanteur qui sait marquer bien ses Phrases et leur accent, est un homme de goût; mais celui qui ne sait voir et rendre que les notes, les tons, les temps, les intervalles, sans entrer dans le sens des Phrases, quelque sûr, quelqu'exact d'ailleurs qu'il puisse être, n'est qu'un croque-sol.*

Punctuation. There is in Music, as in writing, a species of punctuation or repose, which, though not marked between the Phrases whereof a strain or sentence consists, will be easily seen and understood by reference to the following example:





The principal Phrase of which the above example is composed comprises six smaller parts, more or less important or extended, each forming a stop according to the place they occupy in the period of the melody. The first and sixth of these small Phrases are equal in number of notes, each containing only two; the second is longer; the third and fourth nearly of a length; the fifth brings it to a cadence; but the division of Phrases with stops or imaginary punctuation in a melodic period will easily appear by attention to the following melody from the *Don Juan* of Mozart.



In the above it will be seen, that there are two cardinal points, towards which the whole of this Musical sentence tends, namely, the perfect chord of the tonic or key note, and that of its dominant or fifth. We regret that we cannot longer dwell on this head, which the reader who wishes to become a master will find more amply set forth under the article *Ponctuation*, in the *Encyc. Méthod.* Article Musique, which article we have used very freely in some parts of this Essay. These stops or points are called by Dr. Callcott, as by the Germans, Cæsuras, from their analogy to the Cæsuræ in the feet of verses.

Section. The Germans have distinguished a passage consisting of two regular Phrases, the last ending with a cadence, by the name of a Section, two or more of which constitute a Period. A Section is not, however, always divided by Phrases, especially in the legato style of Music. There are Sections in different styles which do not occupy the time of two bars, as there are those which extend over a greater number than two bars or measures; so again in fugue, as well as other Music, the Sections are sometimes so interwoven that practice and experience can alone give the reader a thorough knowledge on the subject. Where two subjects are used in the parts, also in fugues, at the end where the Sections are necessarily interwoven, it is the practice to protract the harmonies so that the measures shall come out regular in the close. So also in vocal Music, the harmony of a Section is frequently protracted for the sake of well expressing the words.

Period. The Period, as we have already observed, consists of one or more Sections; it may be said to resemble the full stop or semicolon in punctuation of writing. When one or more Periods are terminated by the double bar, the whole is called a *Strain*. Those Periods which close with a perfect cadence are, from their last harmony, called *Tonic Periods*, and those terminating with an imperfect cadence are called *Dominant Periods*; but these terms are to be understood as relative to the nature of the cadence only, and not the modulation of the period. The Period, as well as the Section, is interwoven, especially in the fugue Music of the ancient masters.

Coda.

In many movements, the concluding passage, when it occurs after a protracted perfect cadence, is termed a *coda*. In modern Music, the Coda is often preceded by a lengthened shake on a note of the dominant harmony. A Coda varies in length; in some compositions it is extended to several sections, whilst in others it is confined to a single phrase.

PART III.

Composition.

Composition is the art of disposing and arranging Musical sounds into airs, songs, &c. in one or more parts, for voices or instruments, or both. Zarlino describes it as the art of joining and combining concords and discords, which we think rather too circumscribed a view of it, inasmuch as it certainly comprehends the rules, first, of Melody, or the art of writing a single part, that is of contriving and disposing simple sounds, so that their succession may be agreeable to the ear; and, secondly, the art of arranging and concerting several single parts in such a manner as to make one agreeable whole. Of Melody and Harmony we have already treated separately. Here we may stop to remark, that Melody is chiefly the work of the imagination, and therefore the rules of its composition seem only to bound it within certain limits, beyond which the imagination, in seeking after variety, novelty, and beauty, must not wander. But Harmony is the result of judgment, its rules are certain and extensive, and difficult in practice. It must, nevertheless, be remembered that Melody requires a knowledge of Harmony, and though a person unskilled in Music might accidentally hit upon a good air or melody, yet it is from a person of sound judgment that such a production is to be expected most correctly.

tions.

The motion from one note to another in the same part is either *by degrees* or *by skips*; thus, if the interval of a semitone major, or a whole tone be between two notes, the motion is by degree; but if from one a third or more above or below that from which we set out, it is by skip.

Motions considered between two parts, are of three kinds; the first is *oblique motion*, which takes place when one part repeats or holds on the same note, whilst the other moves up or down. The second is termed *direct* or *similar motion*, and is when both parts move the same way, be it upwards or downwards. The third is called *contrary motion*, and is that wherein one part moves downwards whilst the other moves upwards.

n coun-
oint.

Premising this, and that the reader has well fixed in his mind the component parts of all the chords and intervals which have been given in the preceding Part, we proceed to as concise a view as possible of the principles of Composition. The tonic or key note, the fifth, the fourth, and the octave, in all keys, as well major as minor, take their common chords as their accompaniment, the dominant or fifth of the minor keys excepted, which has a major sixth for its accompaniment. The other consonant notes of the octave, namely, the third and sixth, and also the dissonant notes of the key require the uncommon chords for their harmony, namely, the third, sixth, and eighth, except the sevenths of minor keys, which bear the fifth instead. All melodies have the perfect chords of the key they are in for the fundamental basses, and it must be observed, that those melodies are most agreeable that move by conjoint degrees after them, those that proceed by the smallest skips. Formerly, excepting the leap to the octave, none greater than that of the sixth minor was allowed. The leaps of the false relations, [*viz.* a tritonus and a false fifth, were forbidden altogether. Those melodies being least agreeable that go most by leaps, and least by degrees, and the fundamental bass being only used, creating many leaps in its melody, to remedy the defect other notes are used for basses which have obtained the name of supposed basses. These are necessary on many occasions, for, inasmuch as they do not change the harmony, they make the melodies susceptible of great variety; for, using the fundamental and supposed basses as occasion may require, we are enabled to make the parts move together more by conjoint degrees, by which the melodies will sing better. In order to prevent prolixity, we shall, in the succeeding rules, use the key of C as an example of a major key, as we shall that of A for minor keys.

General rules.

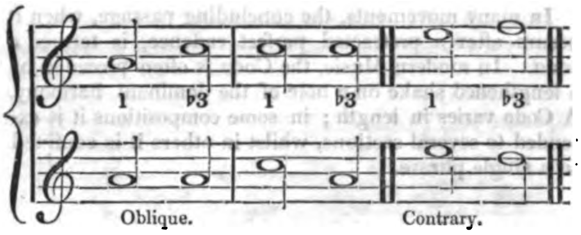
It is customary for every composition to begin with one of the perfect concords of its key note or tonic, *viz.* the octave or the fifth, and it must end in the key note with its common chord for the harmony; it should not begin or end with a sixth, though it occasionally may with a third.

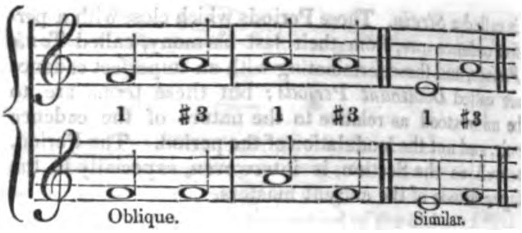
Two perfect concords of the same kind must not follow each other immediately as two unisons, octaves, or fifths, or fourths. This rule does not, however, obtain in the repetition of the *same* notes, this, in effect, being no more than the subdivision of a long note.

Two or more parts should not be so constructed as to move by leaps together, but should proceed as much as possible by contrary motion and single degrees, because, by this means, there will be less danger of falling upon consecutive concords, independent of the melodies being thus rendered more agreeable and better suited to the voice. The rules for the succession of concords will be now submitted to the reader under their different classes, observing always, that it is incorrect to go by similar motion from one perfect concord to another of any kind.

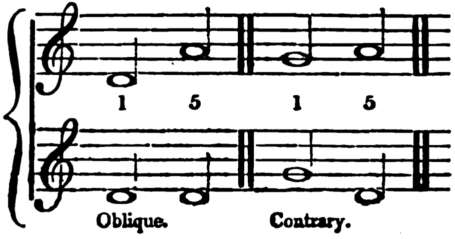
From the unison.

If both the parts move, it is better to proceed from the unison to the third minor than to the major; to the first you must go either by oblique or contrary motion, to the latter by oblique or similar motion, but the first is preferable. Thus,

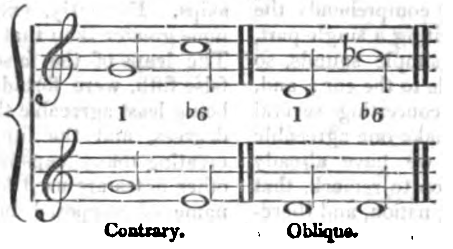




A fifth is to be avoided after a unison by similar motion though good in oblique motion; and allowed in contrary motion if one part move a single degree. Thus,



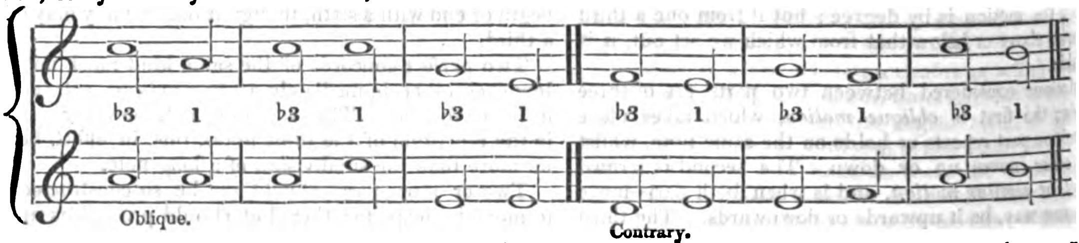
From the unison to the sixth minor may be taken by contrary motion, but it is not considered good by the other motions, because the great leap from it to the sixth major is forbidden.



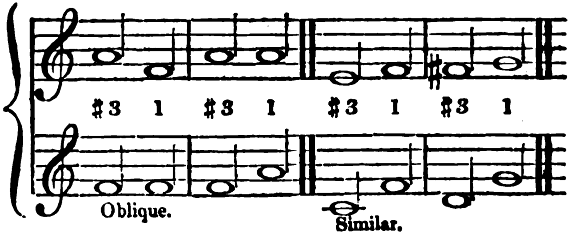
An octave should be avoided after the unison except by oblique motion, inasmuch as it is, in truth, the subdivision of two notes.

From thirds.

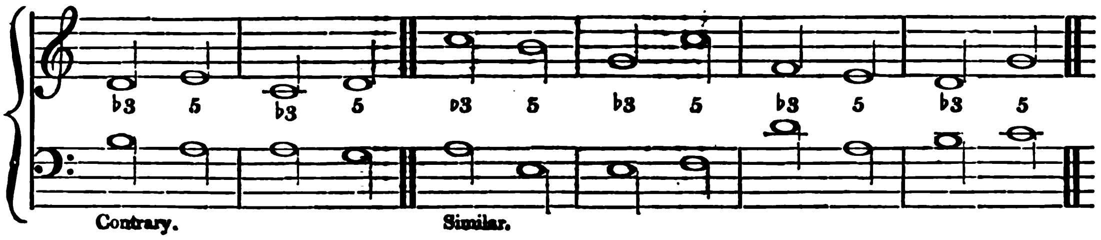
Major and minor thirds, though imperfect concords, are more frequently used than any other. Their effect, either ascending or descending, is agreeable. Major thirds are cheerful in ascending, and the contrary in descent, in the minor a contrary effect is perceptible. In divisions by *supposition*, that is, the use of two successive notes of equal time, one of which, being a discord, *supposes* the other a concord, thirds may follow each other to any extent, but two minor follow each other better than two major thirds. Commencing with the third major is best in ascending, and the converse in descending, changing the quality alternately. From a third we may go to any concord, and from any other concord to a third, but in going from the third to a perfect concord, it is advisable, if possible, to go to the nearest. When the composition consists of many parts, thirds, or their replicates, are most efficient in parts remote from the bass. From the third minor to the unison the better mode is by oblique motion, or by contrary motion. Thus,



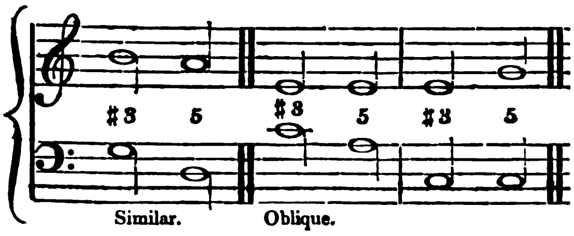
From the major third to the unison is allowed by oblique motion, though better by similar motion, one part ascending a single degree. And, in proceeding from a third to a fifth by contrary motion, it is better to go from the third minor because the danger of falling on the tritonus is avoided.



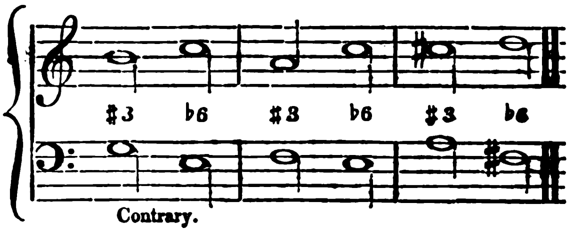
From the minor third to the fifth is better by contrary motion, though also good by similar motion, if one part move a degree. Thus,



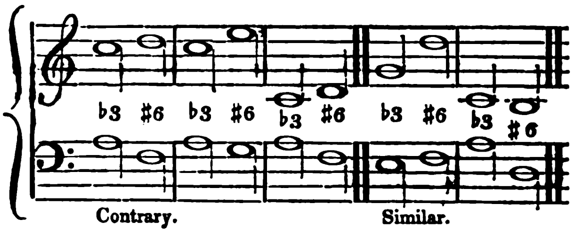
From the major third to the fifth, the progression is better by similar descending motion one of the parts moving a single degree, it is also good by oblique motion. Thus,



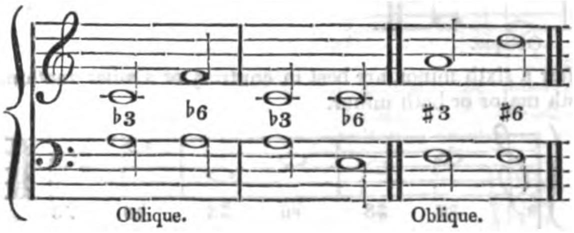
From the major third to the minor sixth, and from the third minor to the sixth major, it is better to go either by contrary or similar motion. In oblique motion the thirds and sixths must be either both minor or both major. Thus,



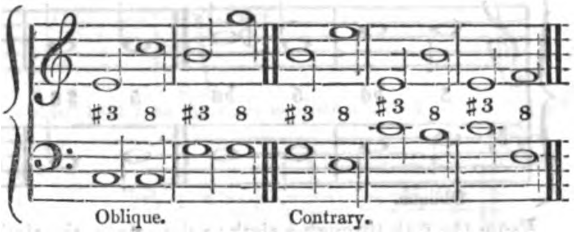
and thus,



and thus,

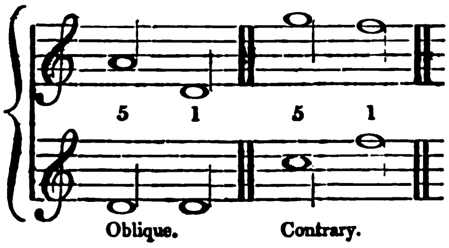


An octave after a third major is good by oblique motion, as also by contrary motion, and it is better when one part moves a single degree. After the third minor an octave is scarcely allowed, and when used should only take place by contrary motion.

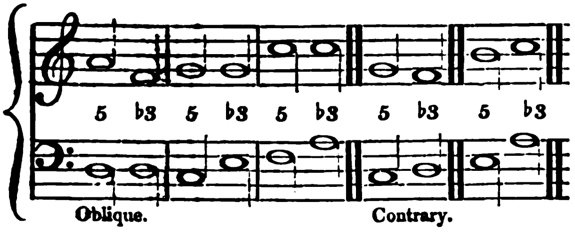


From fifths. After the unison or octave the fifth is the most perfect of the concords. It is best in parts nearest the bass. We may proceed from it by oblique motion to any other concord.

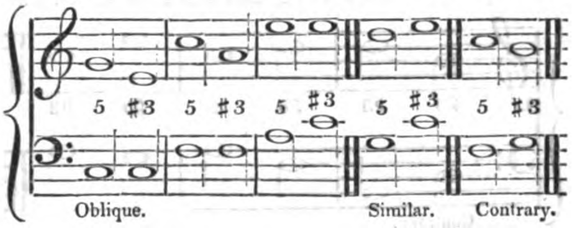
From the fifth to the unison by oblique motion is good, as also by contrary motion, one part moving a single degree, but by similar motion it is bad.



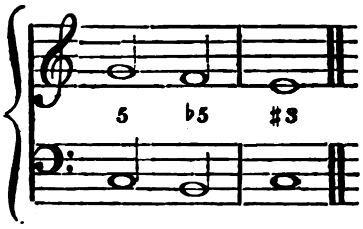
From the fifth by any of the motions you may proceed to either third, but by oblique motion it is best. The next preferable mode of going to the third minor is by contrary motion, and to the third major by similar motion, both of them by single degrees. Thus,



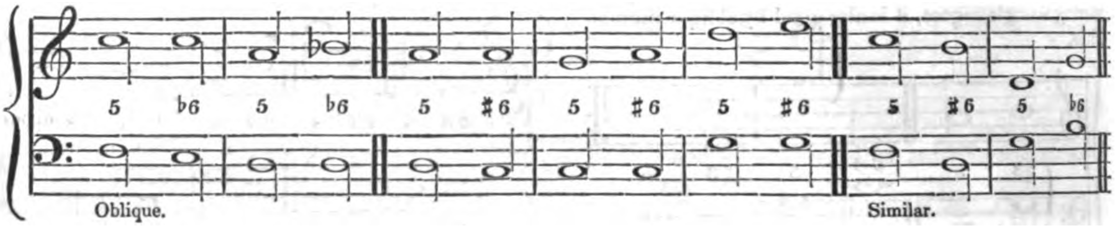
and thus,



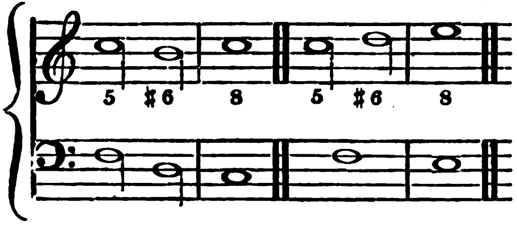
A perfect fifth may be followed by the false fifth if the latter be immediately succeeded by the third major, and that by contrary motion.



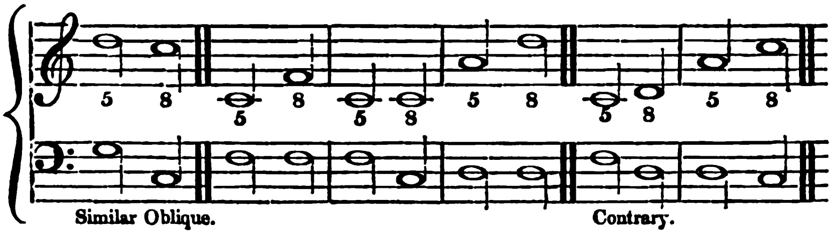
From the fifth to either of the sixths it is better to proceed by oblique motion, though it is allowable by similar motion if one of the parts moves a single degree. It is also allowable ascending, but not in descending, to leap from the fifth to the sixth minor, though not to the major.



From the fifth through a sixth to the octave, the sixth must never be minor, and the motion must be contrary.

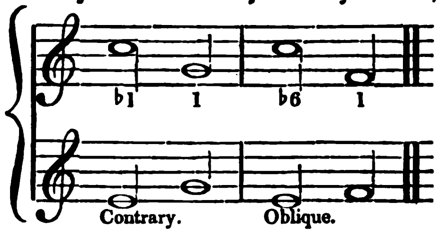


An octave after the fifth in leap by similar motion is to be avoided. By oblique and contrary motion it is good, and if one of the parts move a single degree it is allowable by similar motion.

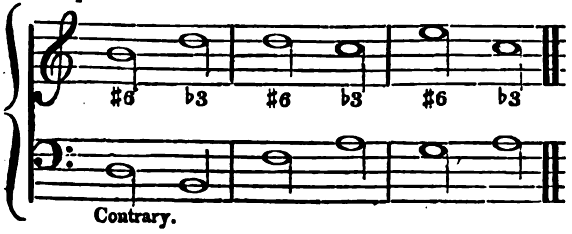


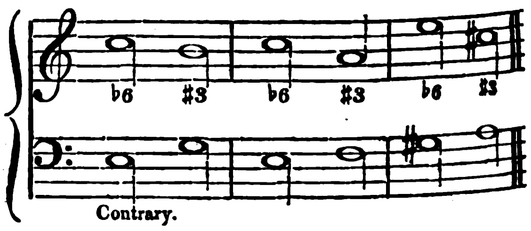
From sixths.

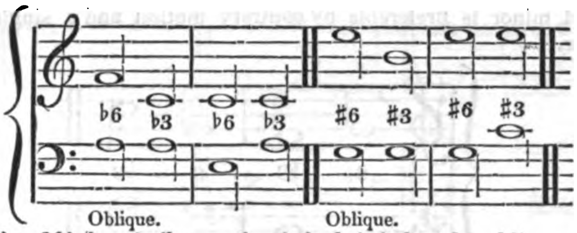
The sixth major naturally moves to the octave. The sixth minor to the fifth. From the sixth minor we may go to the unison but not from the sixth major. It is best by contrary motion, by oblique motion it is not allowed.



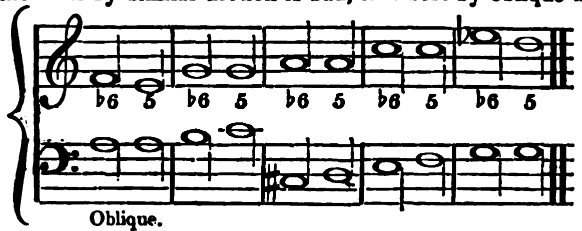
A third minor after a sixth major, and a third major after a sixth minor, are best in contrary or similar motion. In oblique motion the thirds and sixths must be either both major or both minor.



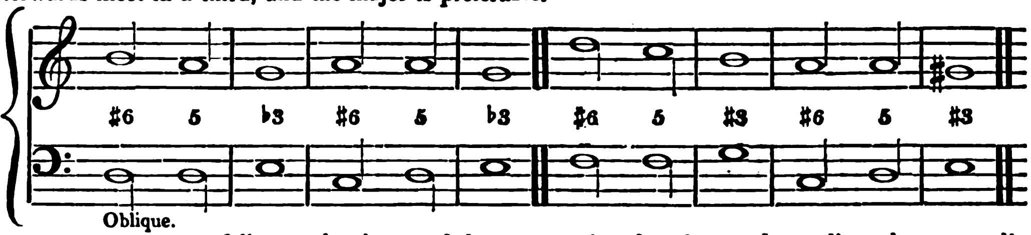




From the sixth minor to the fifth by similar motion is bad, it is best by oblique motion.

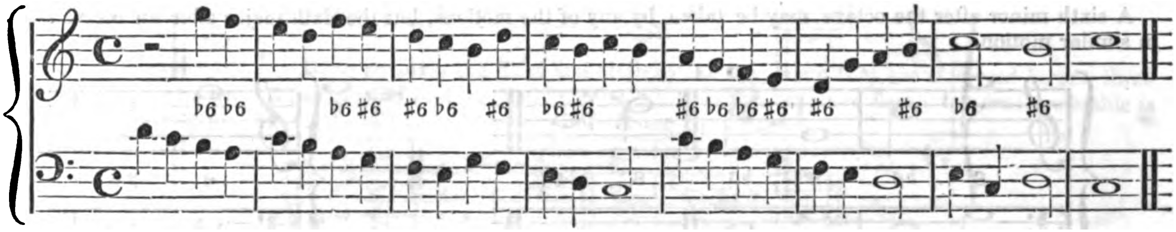


It is only in oblique motion that the progression from the sixth major to the fifth is allowed, and then the parts must afterwards meet in a third, and the major is preferable.

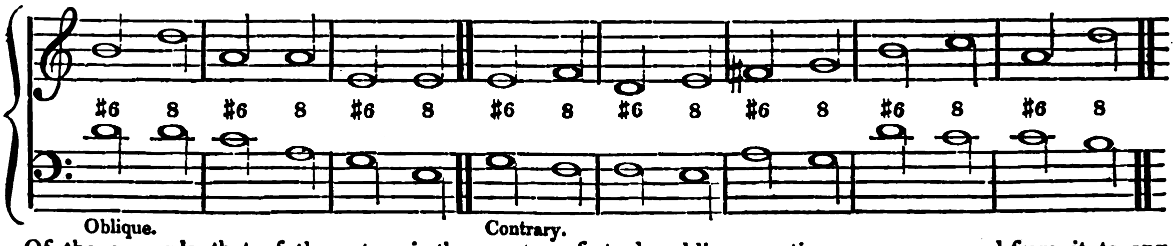


Sixths to any extent may follow each other, and by any motion, but better descending than ascending. In descending begin with the minor and in ascending with the major, in each case changing them alternately. Two major sixths follow better than two minor when one part divides upon the other, also when the parts move by single degrees, but they are not desirable by leaps. In quick divisions they may be used at pleasure if the parts move by single degrees.

Example of sixths:



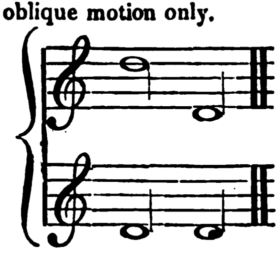
From a sixth minor to the octave is to be avoided. From the sixth major to the octave may be taken by oblique motion, but it is preferable by contrary motion and single degrees. It is bad by similar motion.



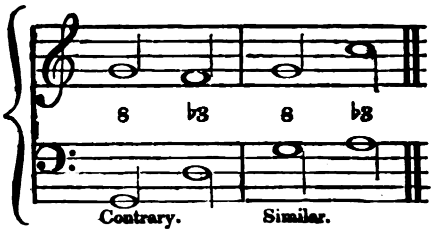
From the octaves.

Of the concords, that of the octave is the most perfect; by oblique motion we may proceed from it to any other concord, except the third minor, but by the other motions we may go from it to the third minor.

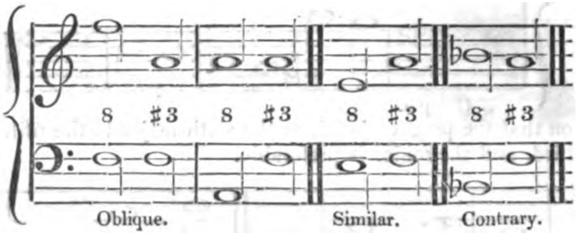
The unison after an octave is allowed by oblique motion only.



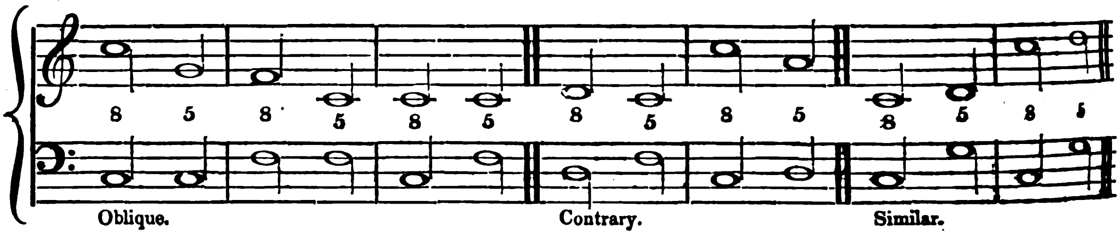
From an octave to a third minor is preferable by contrary motion and a single degree, allowable in similar motion, forbidden in oblique.



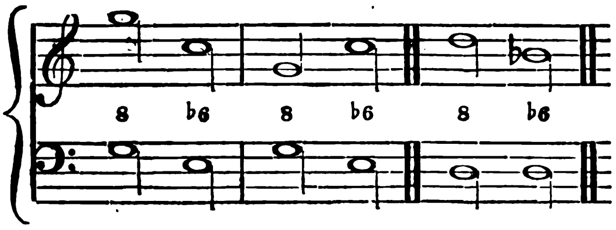
From an octave to a major third is allowed by all the three motions, one part must, however, move by a single degree in similar and contrary motion.

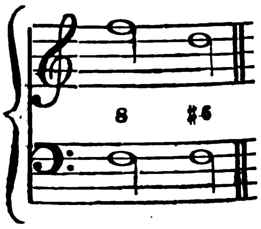


From an octave to a fifth is a good progression in oblique motion, and is permitted in contrary and similar motion, one part moving a single degree, but in similar motion it is forbidden if both parts move by leaps.



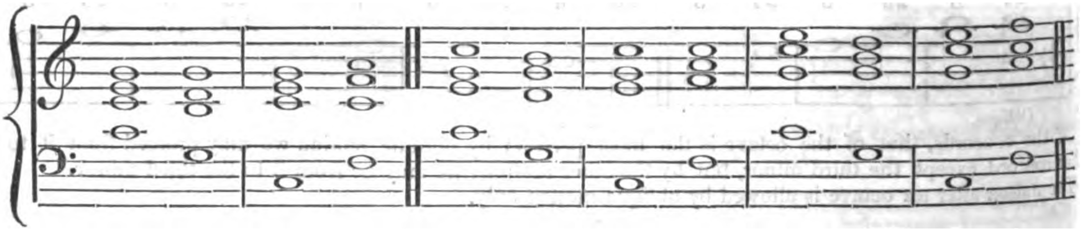
A sixth minor after the octave may be taken by any of the motions, but the sixth major after an octave is bad in similar motion.





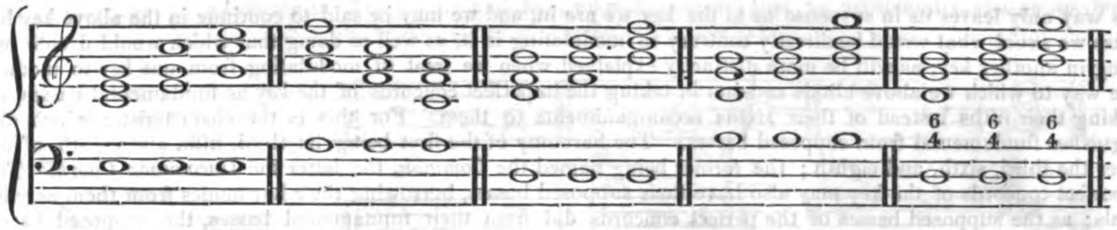
Major keys. It will be convenient, and equally answer the purpose, to use the key of C as an example for major keys in the following pages, as we shall hereafter that of A as an example of minor keys.

The perfect concords of the key are the fundamental basses, and require their common chords for their harmony.

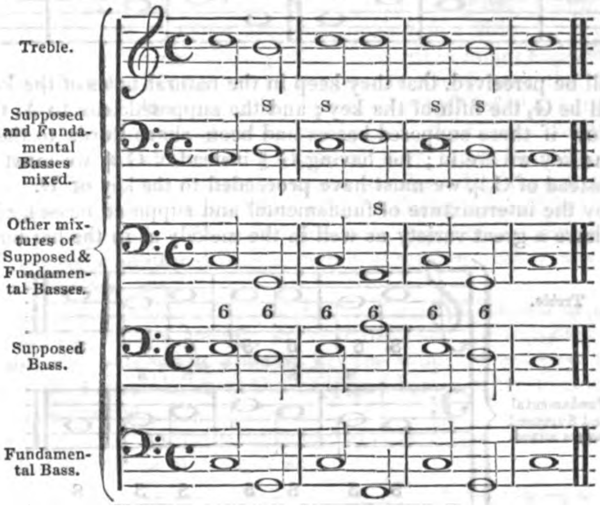


If the third, sixth, and seventh of the key are used as basses with uncommon chords on them, that is, their third, sixth, and eighth, they are supposed basses. Hence it is to be observed, that every bass note which has a sixth upon it is a supposed bass.

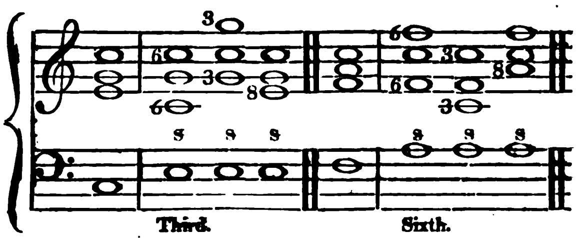
The key note, its fifth and fourth being the fundamental basses of the key, have major thirds for their supposed basses, that is, their thirds may be used as basses. It is only the fifth of the key that has two supposed basses, inasmuch as, besides its third, it may also have its fifth for its other supposed bass.



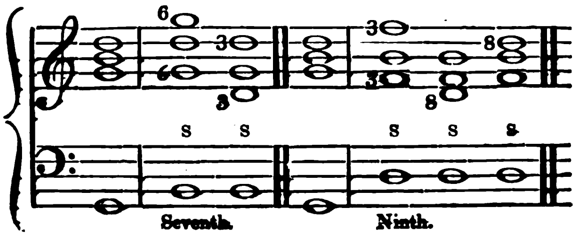
It is right to observe here that the supposed basses do not change the harmonies of their principals, hence the supposed harmony of the third of the key is in effect borrowed from the fundamental harmony of the key note; that of the sixth of the key is borrowed from the harmony of its principal, namely, the fourth of the key; and the supposed harmony of the seventh of the key is taken from the harmony of the fifth of the key; as also that of the ninth, of which it is the second supposed bass, and must consequently have its flat third, fourth, and sharp sixth for its accompaniments, its third being the seventh to the fifth of the key, its fourth the octave of that fifth, and its sharp sixth being the third to that fifth, which is the fundamental bass, to which the ninth, as fifth to it, serves for a supposed bass. In the following example, where the bass is supposed, it is marked with an S.


Treble.
Supposed and Fundamental Basses mixed.
S
S
S
S
S
Other mixtures of Supposed & Fundamental Basses.
6
6
6
6
6
6
Supposed Bass.
Fundamental Bass.

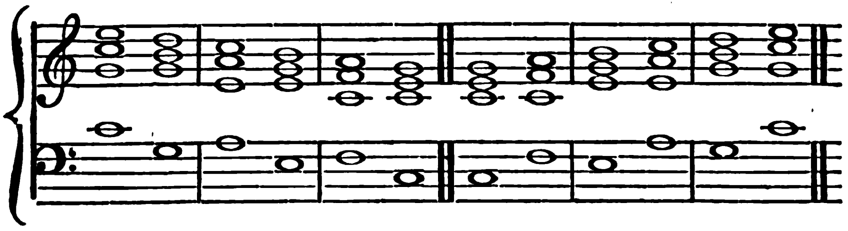
In the accompaniment, or making parts on the third and sixth of the key, when they are supposed basses, three methods may be adopted. The first and best is, doubling the sixth to the supposed bass; the next preferable is that of doubling the third to it; the last and worst way is doubling the octave.



In the accompaniment upon the seventh and ninth of the key, that is making parts on them when the basses are supposed, only two methods are used. For the seventh the best way is to double the sixth; the other way is to double the third to the bass. For the ninth the preferable method is to double the third, the other way being to take the octave to that bass.

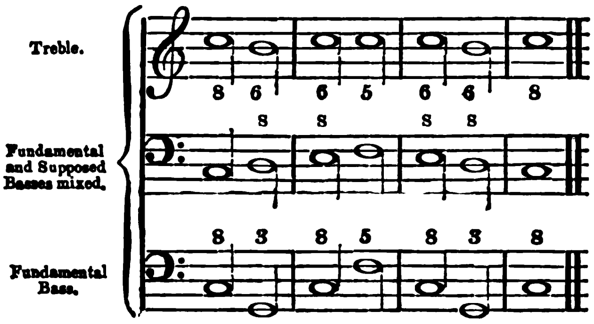


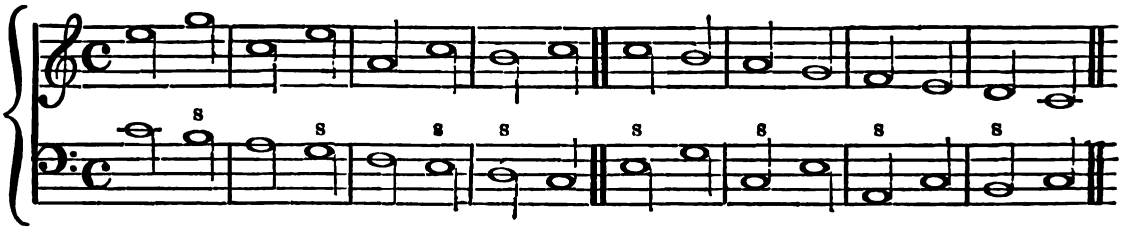
Thus far on the fundamental and supposed basses of the perfect concords of the key. There is, however, another way of modulating which produces great variety. We are still speaking of the key of C, and in strictness this way only leaves us in suspense as to the key we are in, and we may be said to continue in the above key because we avoid what would be directly contrary to modulating in it, as well as doing that which would decide our being in another key, as will be more distinctly explained when we treat of modulating from one key to another. The way to which we above allude consists in taking the imperfect concords of the key as fundamental basses, by making their fifths instead of their sixths accompaniments to them. For this is the characteristic which distinguishes fundamental from supposed basses. The harmony of the first being its third, fifth, and eighth, of the latter the third, sixth, and eighth; the former being named the *Common*, the latter the *Uncommon Chord.* The imperfect concords of the key may also have their supposed basses, borrowing their harmonies from them as principals; as the supposed basses of the perfect concords did from their fundamental basses, the supposed basses differing from the others, inasmuch as the supposed basses of the perfect concords are sharp thirds above them, and those of the imperfect concords are only flat thirds above them.



In the above examples it will be perceived, that they keep in the natural notes of the key; thus the supposed bass to E, the third of the key, will be G, the fifth of the key; and the supposed bass to A, the sixth of the key, will be C, the octave of the key. Now if these supposed basses had been sharp thirds to their fundamental basses, we should have no doubt as to the key we are in; for having G ♯ instead of G ♮, we must have gone from it into the key of A; and having C ♯ instead of C ♮, we must have proceeded to the key of D.

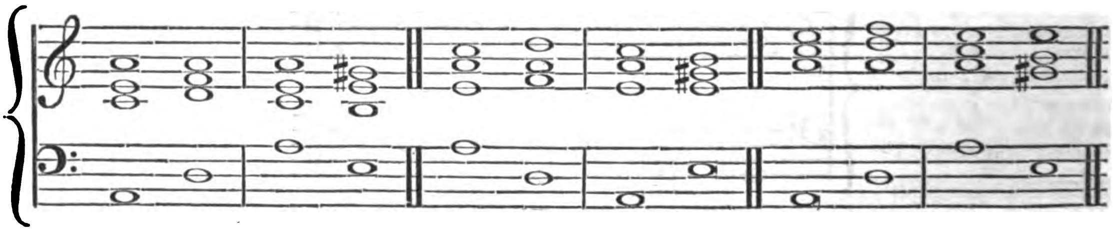
Hence it is apparent that by the intermixture of fundamental and supposed basses, of the perfect and imperfect concords of the key, we may have a great variety as well in the melody as in the harmony of the key used.



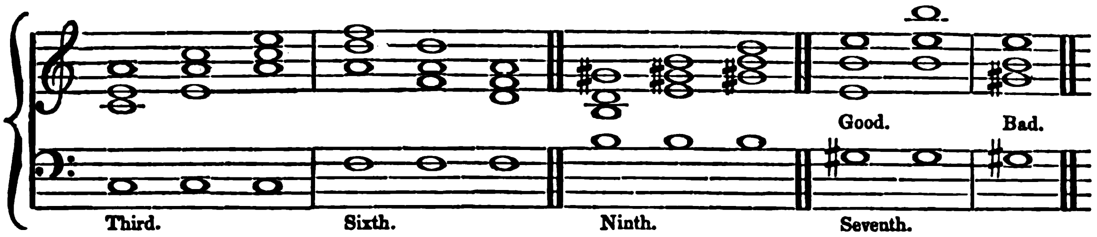


Minor keys. The major keys have been treated of with the key of C, as an example by which the reader is unembarrassed with sharp or flat signatures; for the same reason we choose the key of A as an example for minor keys.

The perfect concords of this key, as those of major keys, *viz.* the unison, fourth, fifth, and octave, require their common chords for their harmony; with this difference, that in it the key note and the fourth only have their thirds flat. The fifth of the key retains the sharp third, although naturally left flat in the diatonic scale of this key; for if it were left flat the key would not be decided as that of A. Hence in this, as in all other keys, the third of the fifth of the key is always major.



The imperfect concords and the discords of the key take the uncommon chords for their harmony, but the G must be sharpened if we decide the key of A: and here we will observe, that no accidentally sharpened note should be ever doubled in plain counterpoint, either in a major or a minor key.



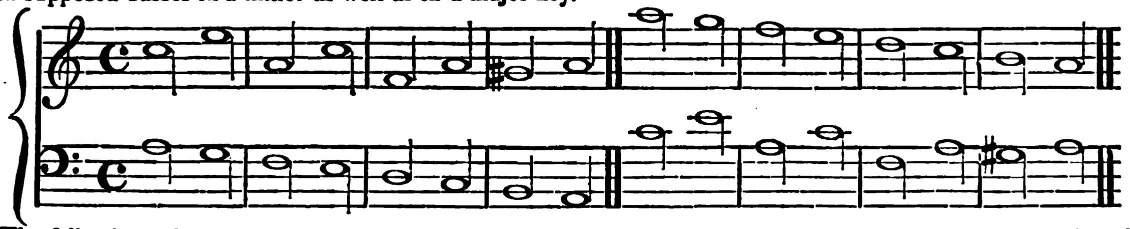
If the imperfect concords and the discords of the key are used as basses, with the uncommon chords for their accompaniments, those basses are supposed basses in all keys minor as well as major; but the seventh of the key of E in the diatonic scale, is accompanied by a fifth instead of a sixth. As the supposed basses take their harmonies from those of the fundamental which they represent, the third in a minor key consequently borrows its harmony from that of the key note. The sixth from that of the fourth of the key. The seventh being in lieu of the fifth of the key, takes its harmony from that of the fifth; and the ninth in flat as well as sharp keys is a supposed bass to the fifth of the key, except as above in E, where the ninth being only a semitone major above the octave cannot be a supposed bass to the fifth of that key, being but its defective fifth.

The difference between the supposed basses of the perfect concords of minor and major keys, is, that in the latter the thirds are sharp above their fundamental basses, whereas in the former the third and sixth of the key are supposed basses, a flat third above their fundamentals; but the seventh of the minor key is a supposed bass, a sharp third above its fundamental bass, inasmuch as in the key of A, the G must be sharpened to decide the key.

The ninth of a minor as well as a major key of a supposed bass, must have its flat third, fourth, and sharp sixth as its accompaniment; the sixth being sharp, because, as above mentioned, the G must be sharpened to decide the key of A. Hence the third, fourth, and sixth of the ninth of a minor key being the same as in a major key, the explanation need not be repeated. The same rules also apply to accompaniments upon the third, sixth, seventh, and ninth when they become supposed basses, merely observing, that if any notes are accidentally sharpened, such must not be doubled in the parts.

The rules for making the imperfect concords of the key fundamental basses in major keys, by putting their common chords for their harmonies, and of having, in their turn, sets of supposed basses, may also be used in a minor key, with this caution, that whereas in a major key the supposed basses of the imperfect concords of the key are flat thirds above their fundamentals, so in the supposed basses of the imperfect concords of a flat key the thirds are sharp above their fundamentals.

The same attention should be paid to the melodies going by degrees and leaps, and the mixture of fundamentals and supposed basses in a minor as well as in a major key.



The following rule is a general one for keeping in any key; it is, however, included in what has been given in the preceding pages, of which it may be considered a summary. It is, that the second of the key must always have a sharp sixth, the fourth of the key always have a third similar to that of the key note, that (in E excepted) the fifth of the key a sharp third, and the seventh of the key a flat sixth, (except in E.)

Descant, figurate counterpoint.

Descant, which is the art of composing in several parts, is threefold. *Plain*, which is the groundwork and foundation of all Musical compositions, consists entirely in the proper placing of several concords as accompaniments to every note of the key we are in. The Italians call it *canto fermo;* in English it is known by the name of plain or simple counterpoint, as being an arrangement of note against note in concords only. The preceding portion of this Part has been devoted to this section of the subject. *Double descant* is that in which the parts are so contrived that the treble or any high part may be made the bass, and the contrary; this will incidentally be noticed in speaking of *figurate or florid descant*, which consists in a mixture of concords and discords following each other, and may be termed the ornamental and rhetorical part of Music, as it induces all the varieties of points, syncopes, diversities of measures, and all that is capable of adorning a composition. By the Italians it is called *canto figurato*. Preparatory to entering upon this it will be necessary to consider the method of preparing and resolving discords.

Preparatio and resolu tion of dis cords

It has already been stated that seconds and sevenths are the natural discords; before, however, showing how they are to be used, we will observe that they may be prepared and resolved either in the upper part or in the bass, the interval being reckoned either as ascending from the bass to the treble, or as descending from the upper part to the bass, as the discord may chance to be employed.

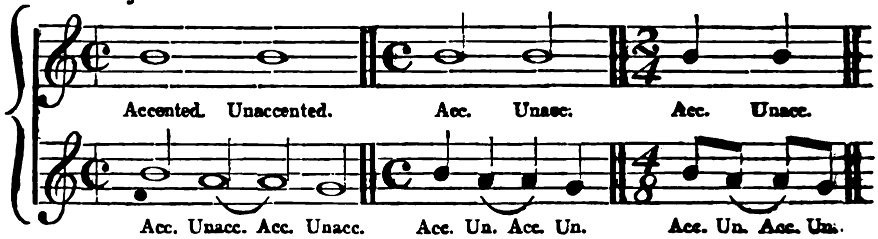
In harmony, discords are considered as so made by the note next immediately above them being struck with them. Thus the second and seventh, as also any other note, as a third, fourth, fifth, sixth, or an eighth, may be made a discord. Therefore a discord is in harmony the lowest of two adjoining notes that sound together.

Hence in the case of the second, which is not really the discord though so called, it is the unison at the bottom which is the discord, being so made by the second; and it might fairly be said that the rule is vague in terms which declares that the second must be prepared and resolved in the bass. Practice, however, having so established the terms, we leave them as we find them to avoid intricacy.

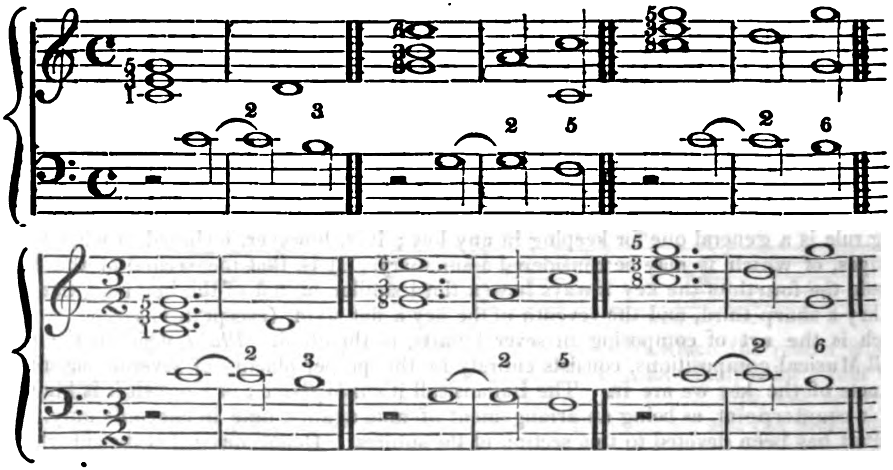
In practice, although there be only two natural discords, three discords are reckoned, namely, the second, the ninth, and the seventh. The ninth is, indeed, only a replicate of the second if simply considered, yet being differently used it is differently treated; inasmuch as the ninth being made a discord by the third, its necessary accompaniment, it is always prepared and resolved in the upper part, whereas the second is universally prepared and resolved in the bass; besides which it may be used in two parts, which is not allowable with the ninth.

It is most common to prepare and resolve the seventh in the upper part, but it is nevertheless sometimes prepared and resolved in the bass, on which account, perhaps, it has had two different names to distinguish it; but practice has not encouraged the distinction, because the seventh prepared and resolved in the bass is in fact nothing but the second; because this seventh in the bass is made a discord by the second or its replicate, or the note next above it, as it is also its necessary accompaniment; whereas the seventh in the upper part is really what it is called, being made a discord by the bass, the octave (below) to the note which makes such seventh a discord, and which is represented by the octave below.

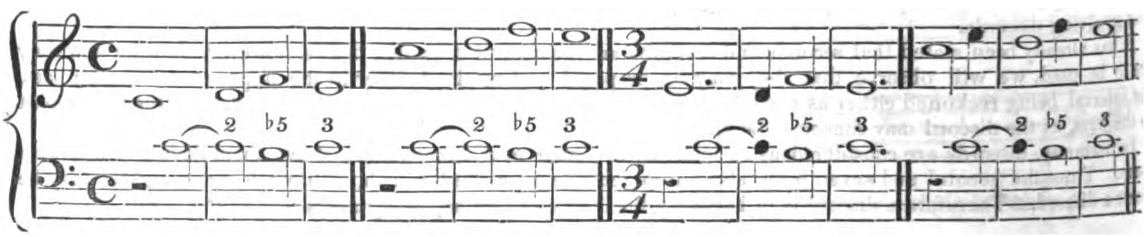
When a note is treated as a discord it must be prepared in the unaccented part of a bar, by being there struck as a concord; in the following accented part of the bar, the same note holding on, is made a discord by sounding with it the note next above it or its replicate; and in the next following unaccented part of the bar, the discord is resolved by descending a single degree, either of a whole tone or semitone major to a concord. Where there are, in common time, two equal notes in a bar, the first is accented and the second unaccented; but as we have already explained accent, we refer our reader back to what has been said under that head, merely subjoining here an illustration of the rule just above mentioned.



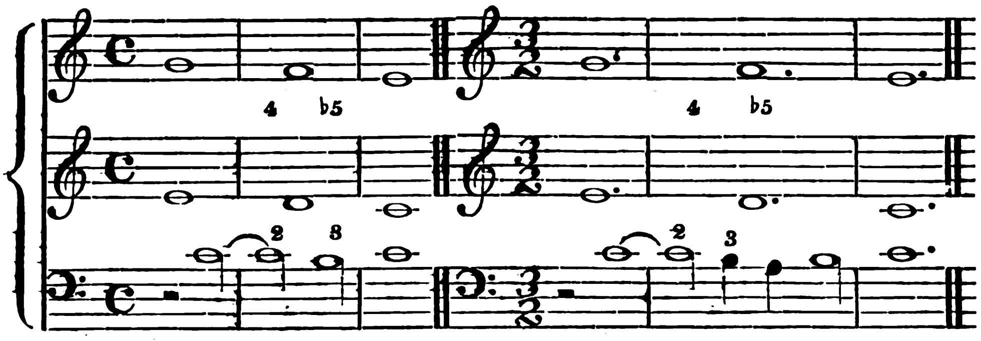
The second. There are two sorts of seconds, major and minor; the former consists of a whole tone, while the latter contains a semitone major. Both of them are prepared in the bass or lower part. The major second may be prepared by any of the concords, and resolved in any but the eighth; it must consequently fall to the resolution, that is the lowest note of the two sounds, or discord must.

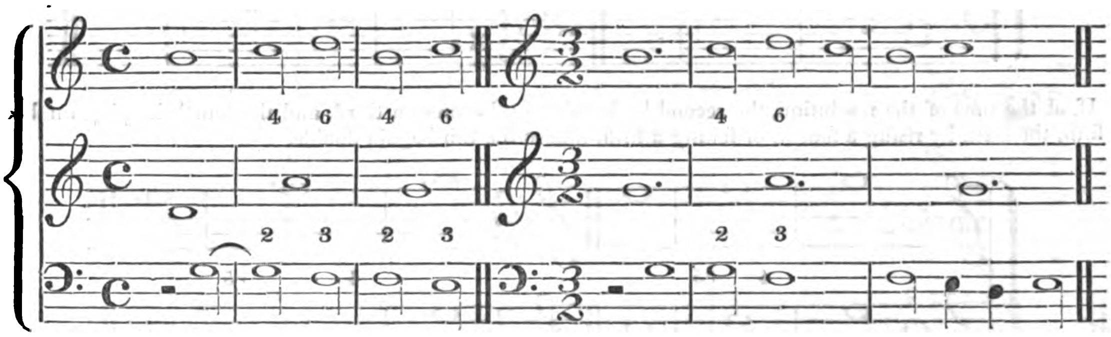


Besides this resolution of the second, a false or defective fifth may be the resolution, in the treble rising a third to it; but then, the bass must afterwards rise one degree, and the treble at the same time descend one degree, in order to resolve the false fifth. In three parts, the accompaniment to this second is sometimes the fourth and sometimes the fifth.

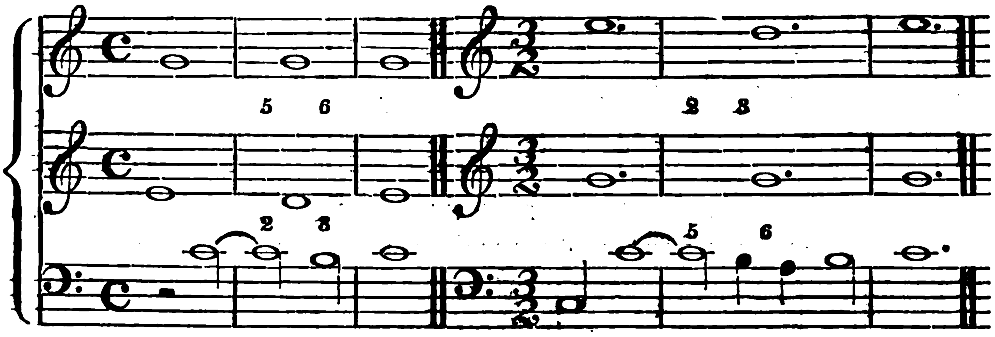


If the fourth be taken with the second, and the two upper parts keep on the notes they previously had, the bass descending one degree for the resolution, the second thus becomes a third, and the fourth will become a perfect or a false fifth, the last being preferable. When, however, the fourth instead of holding on rises one degree it becomes a sixth.

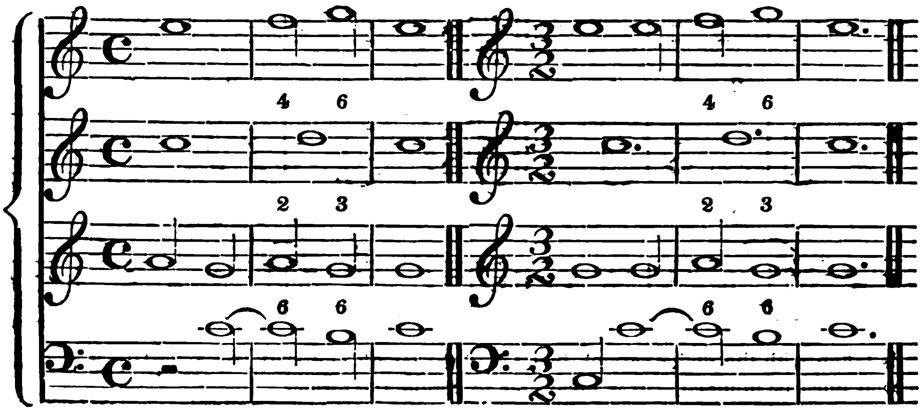




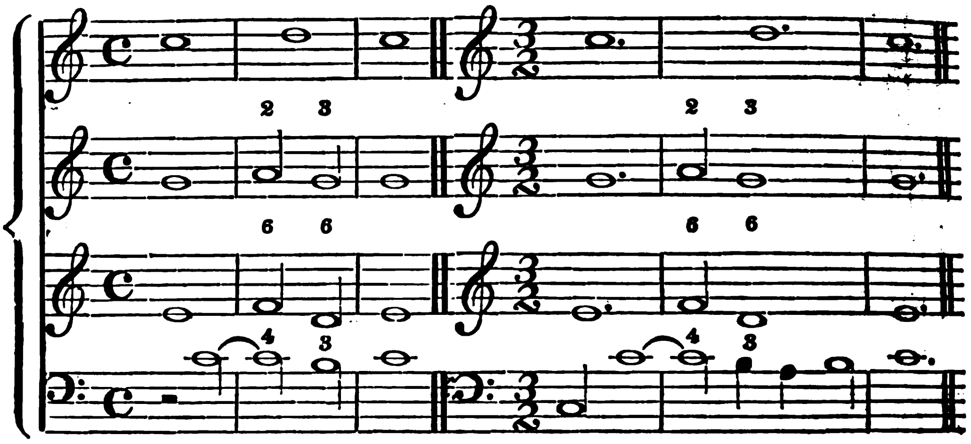
If the fifth is taken with the second, and the two upper parts hold on the same notes, the bass descending one degree for the resolution, the second thereby comes to be a third, and the fifth a sixth. In four parts, this second is accompanied by the fourth and sixth. The fifth may also be used instead of the fourth and sixth.



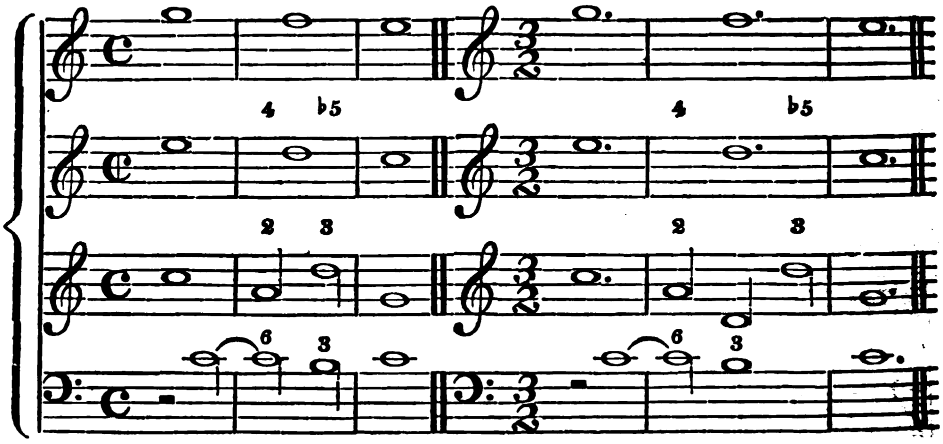
When the fourth and sixth are taken with the second, if the bass descend one degree to the resolution, the fourth rises one degree and so becomes a sixth, and the sixth descends one degree and thus continues to be a sixth; in using this method the sixth is doubled, which is the best way.



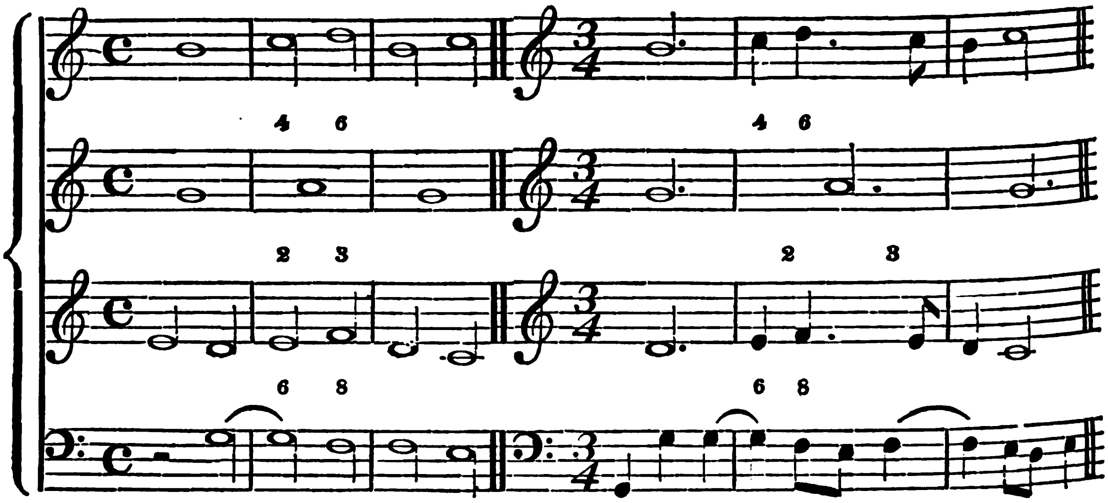
There is another way by which, at the time of the resolution, the second keeping on becomes a third, and the fourth dropping a third also becomes a third. The sixth falls one degree and continues a sixth; by which method the third is doubled.



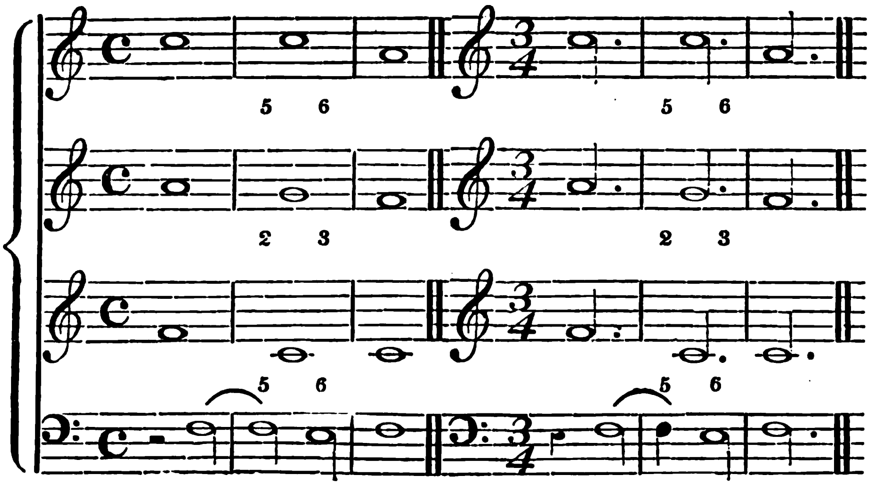
If, at the time of the resolution, the second by keeping on becomes a third, and the fourth keeping on becomes a fifth, the sixth by rising a fourth, or falling a fifth, makes the third again double.



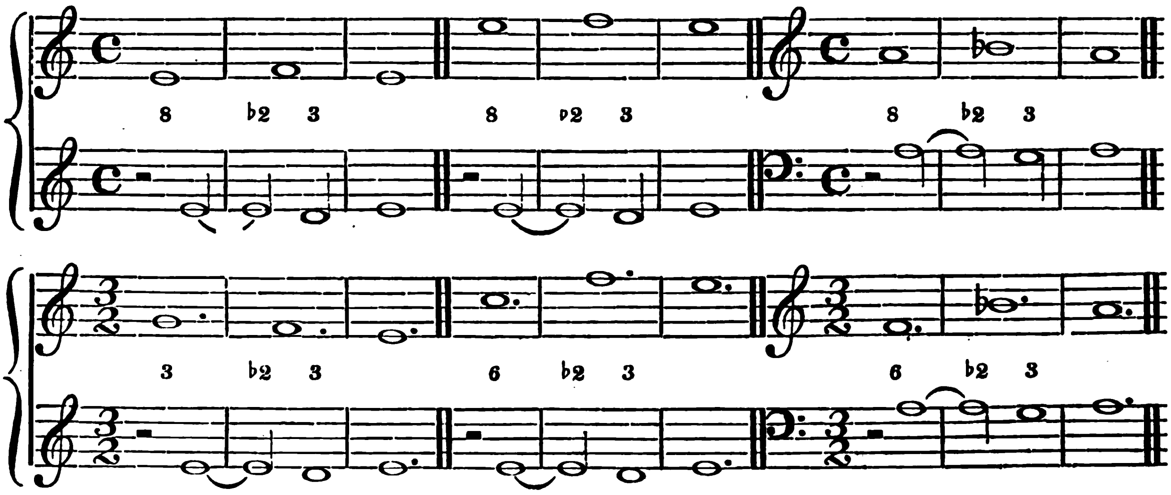
The last and least harmonious way is, when the fourth rising one degree becomes a sixth, the sixth rising one degree becomes an eighth, and the second by keeping on becomes a third on the resolution.



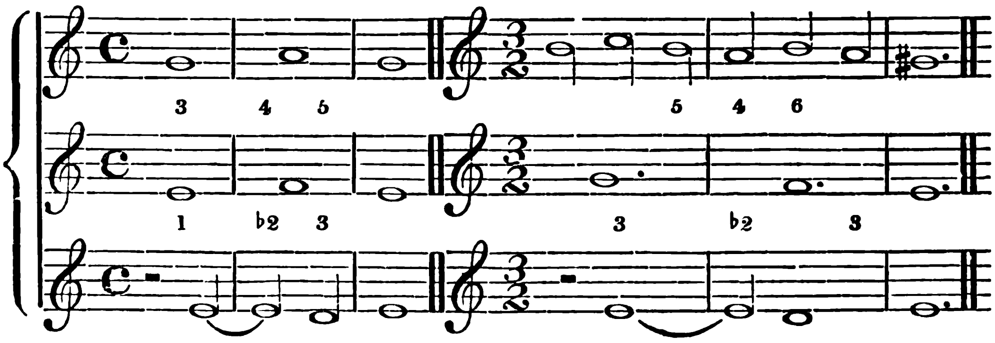
If the fifth is taken with the major second, instead of the fourth and sixth for completing the fourth part, the fifth or the second must be doubled. It is preferable to double the former



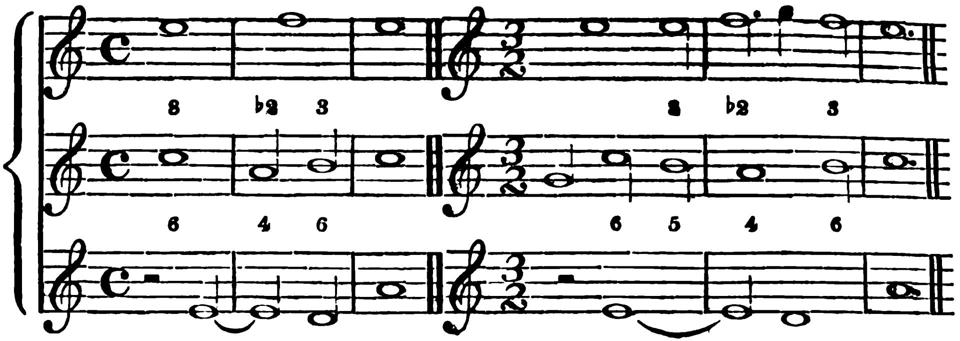
The minor second, which the reader will recollect is but a semitone major above the unison or bass, has the same preparation as the major second, except in the fifth, in which it must not be prepared. And it is necessary to observe that the best resolution of it is into a third.



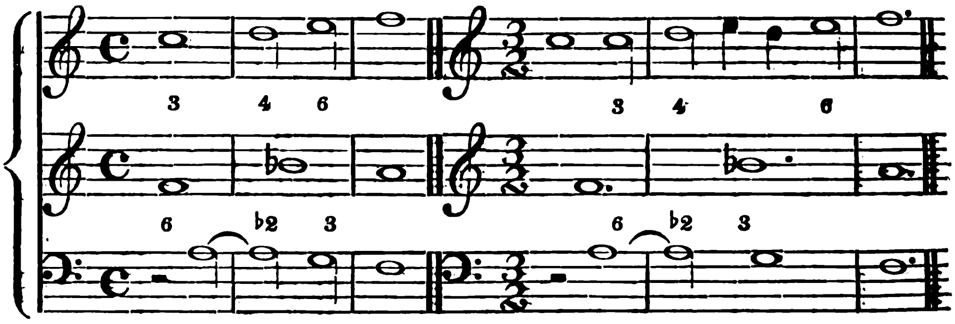
When the minor second is employed in three parts, it must be accompanied with the fourth and never with the fifth. There are three ways of using it. First. The fourth with the minor second, in which case the upper parts hold on, whilst the lower or bass descends to resolve it; thus the second becomes a third and the fourth becomes a fifth, then the two upper parts both fall one degree and the bass rises one degree, and the whole may serve as a final cadence.



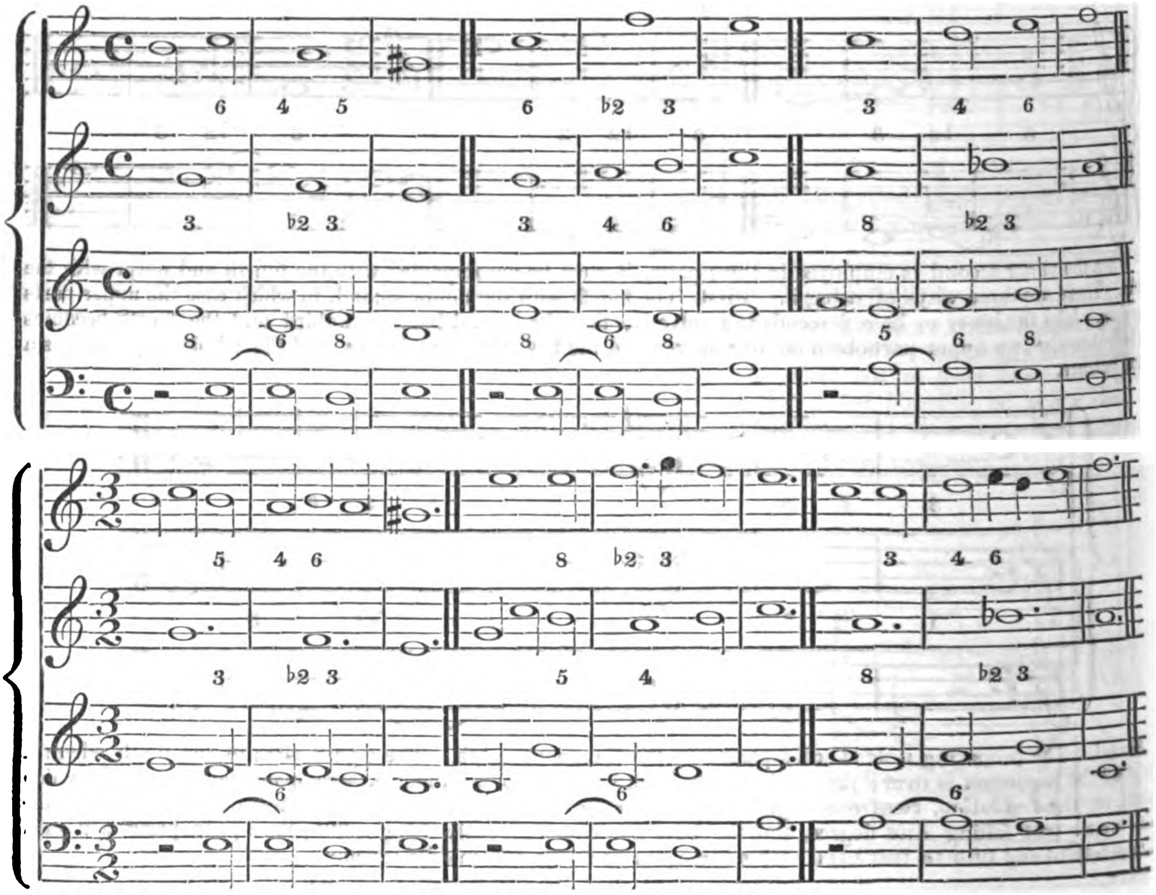
Second. The preparing note is accompanied by the sixth and eighth. The eighth rises to the ninth where it stays till the resolution is over; the sixth falling a third thus becomes a fourth, accompanying the second, which fourth, on the resolution, rises one degree, thus becoming a sixth; this afterwards rising one degree more, the other upper part falling one degree, and the bass contemporaneously rising a fifth, the upper parts will then become a third and fifth to that bass. This arrangement serves as a middle cadence.



Third. The preparing note is accompanied by the third and sixth. The part in which the third appears is to rise one degree and become a fourth ; that part carrying the sixth is to rise a fourth, thus becoming a second, which holding on is a third on the resolution ; whilst the fourth rises one degree becoming a sixth, this sixth afterwards rising one degree more, the other upper part and the bass each falling one degree, the upper become a third and eighth to that bass.



When four parts are employed, the sixth and fourth are taken with this second. As in the following example

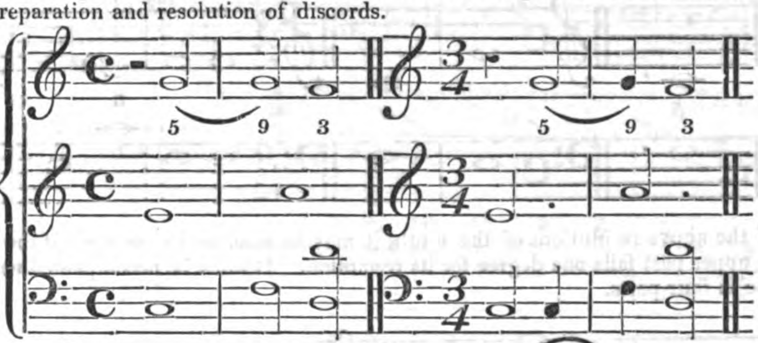


The ninth.

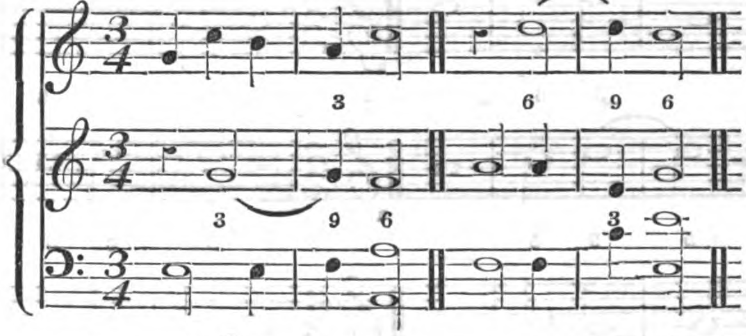
It has already been stated that the discord of the ninth is not so called merely because it is the replicate of the second, and that the distinguishing character between these discords in harmony, does not arise from the distance between the two notes in the several parts, inasmuch as the interval, if a real second or a real ninth, bears the name of the second if prepared and resolved in the bass, but invariably of a ninth if prepared and resolved in any of the upper parts. Like the second, the ninth is of two sorts, major and minor; but each is prepared and resolved in an upper part; and to use them at all there must be at least three parts, because of their requiring the accompaniment of the third or its replicate, by which they are made discords.

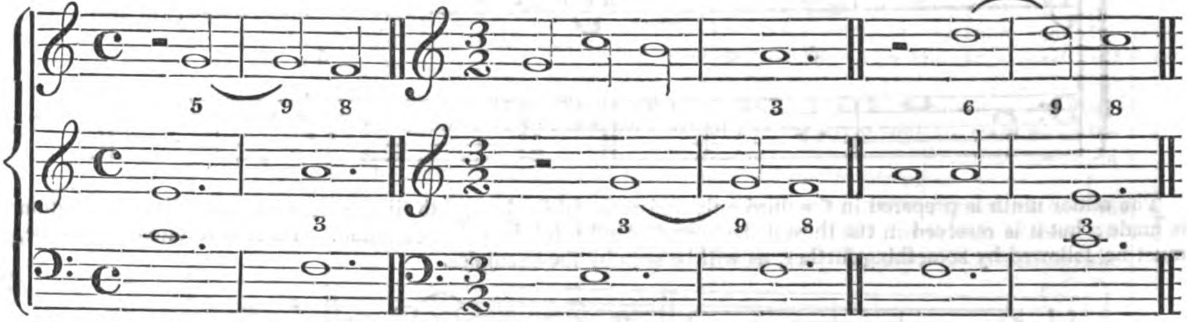
The major ninth is prepared by a third, by a fifth, and occasionally by a sixth, never by an eighth. Its resolution is by a third, a sixth, or an eighth, from each of the concords in which it is prepared. In most of the following rules we shall not give an example in each time, but alternately; from those that have already been given the reader will have become acquainted with the accented and unaccented parts of the bars which are necessary to be attended to in the preparation and resolution of discords.

The Bass falls a third or rises a sixth.

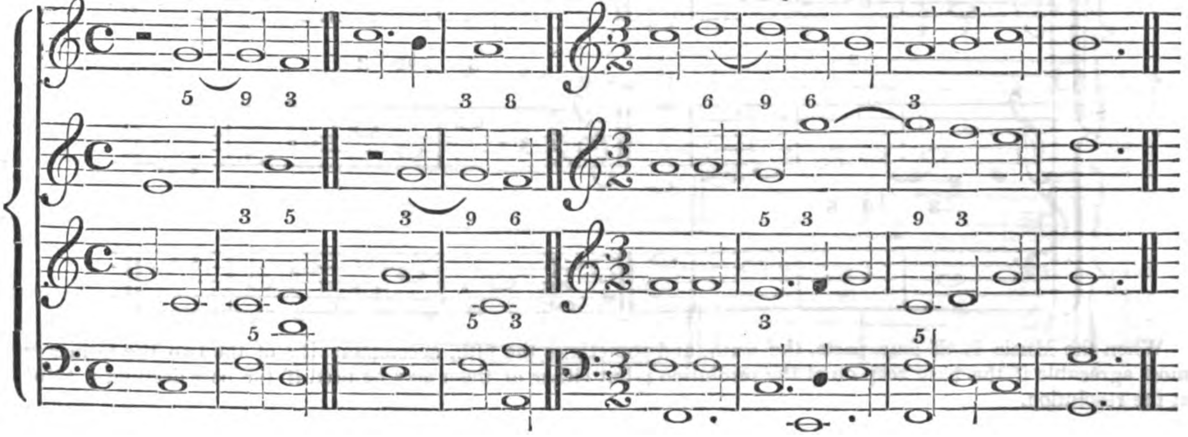


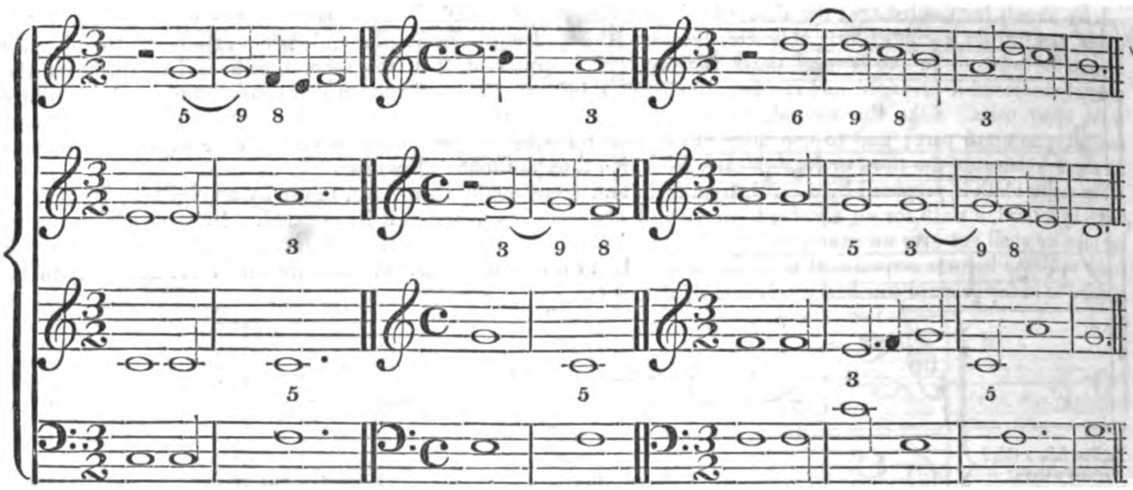
The Bass falls a third or rises a sixth.



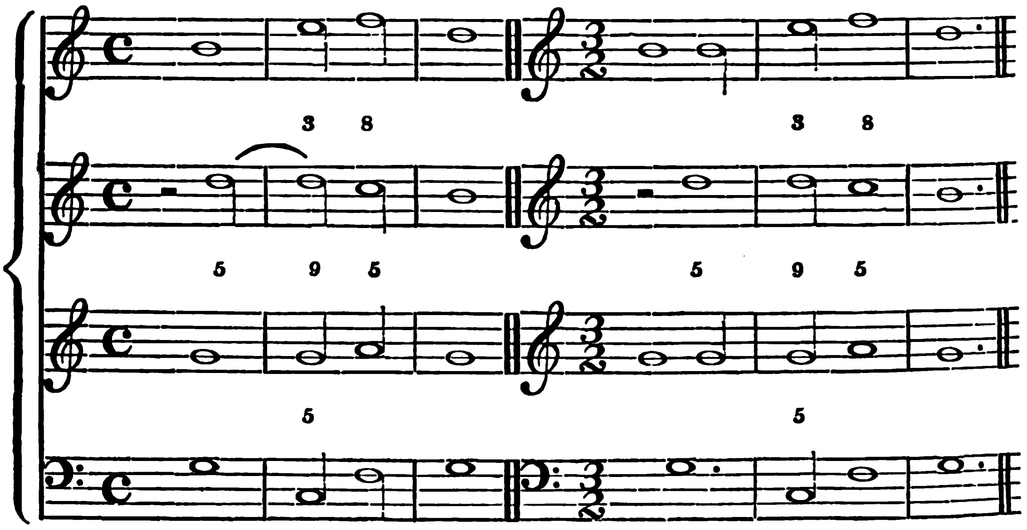


The third and fifth must be taken with the ninth when it is used in four parts.

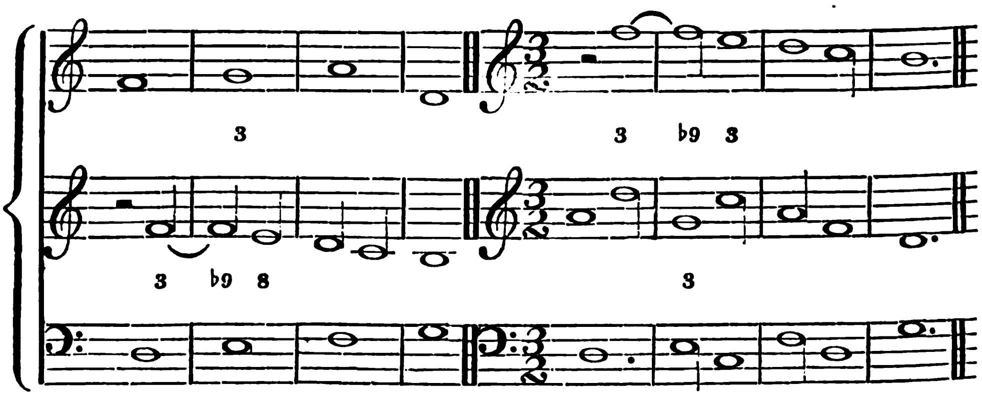




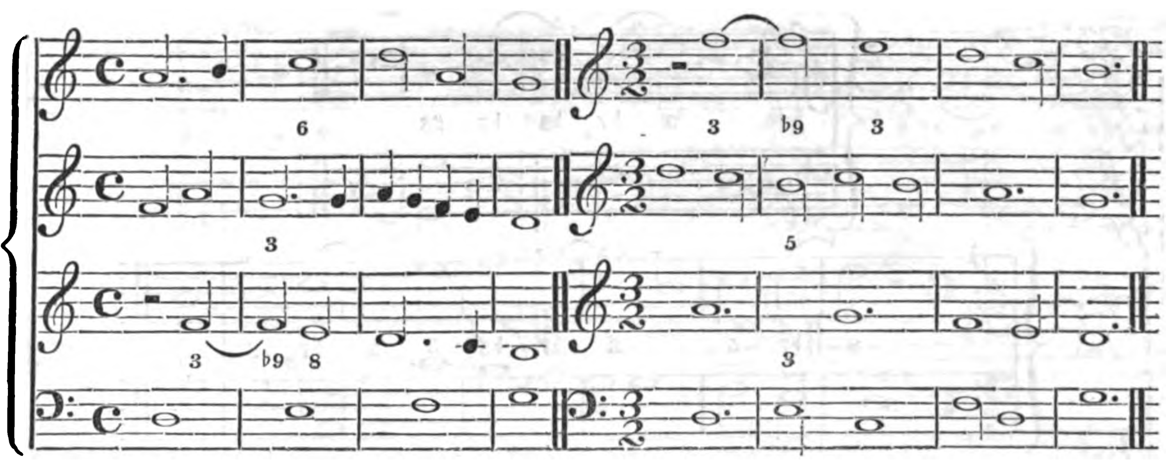
Independently of the above resolutions of the ninth, it may be resolved by the fifth, if the bass rise a fourth or fall a fifth when the upper part falls one degree for its resolution. It must be accompanied at the resolution by an eighth if the piece be in four parts.



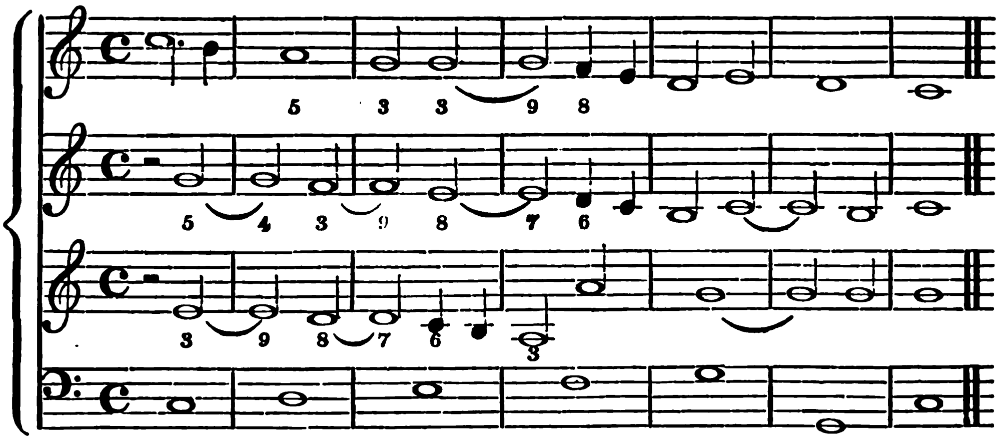
The minor ninth is prepared in the third only and resolved in the eighth, if the bass hold on till the resolution is made; but it is resolved in the third if the bass descend a third on the resolution. These resolutions, however, must be followed by something further, as will be seen by the examples.



When the Music is of four parts, the sixth, and sometimes the fifth, accompany it; of the two the former is most agreeable if the bass keep on at the resolution; but either of them may be used if the bass descend a third at the resolution.



The ninth may have other discords mixed with it. For example, it may be mixed with the fourth, and in that case the fourth must be also prepared and resolved as a discord. The ninth may be also mixed with the seventh, which must also be separately prepared and resolved. It is to be held in mind, that when the fourth and ninth are mixed the fifth must be in the fourth part, and when the seventh and ninth are mixed the third must be in the fourth part.

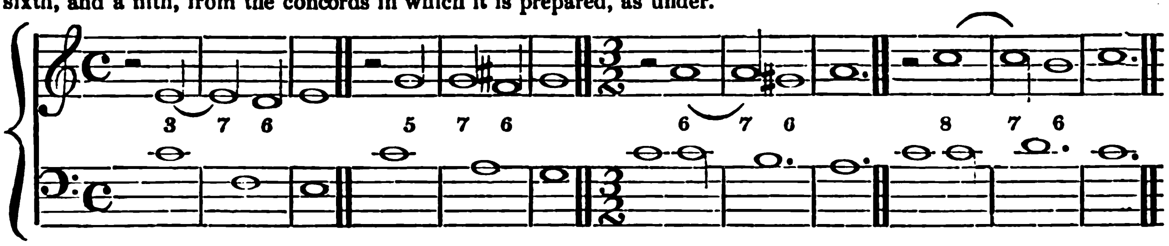


The seventh.

The other natural discord is the seventh. Which is also of two sorts, the major, which contains one semitone major less than the octave, and the minor, which is one whole tone less than the octave. These sevenths are both prepared and resolved in the treble as well as in the bass, most generally, however, in the upper part. They will be here classed under those two heads.

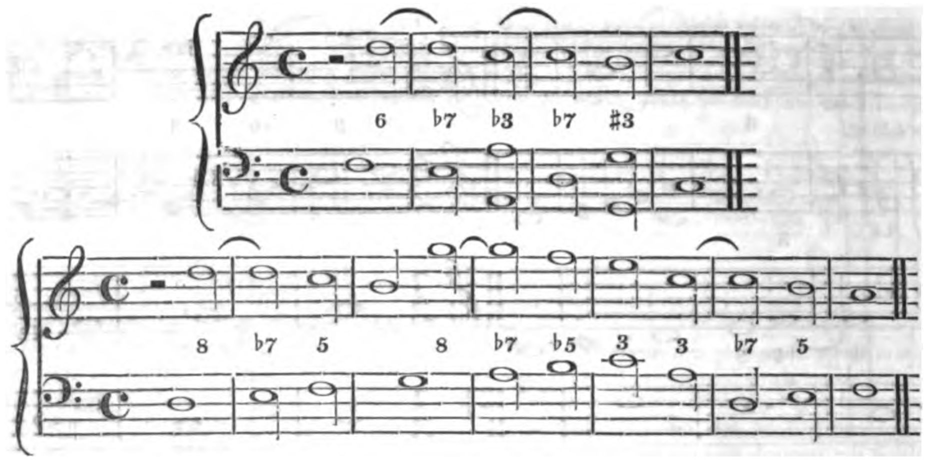
Prepared and resolved in the treble.

The preparation of a major seventh, is a third, a fifth, a sixth, or an eighth. Its resolution in a third, a sixth, and a fifth, from the concords in which it is prepared, as under.

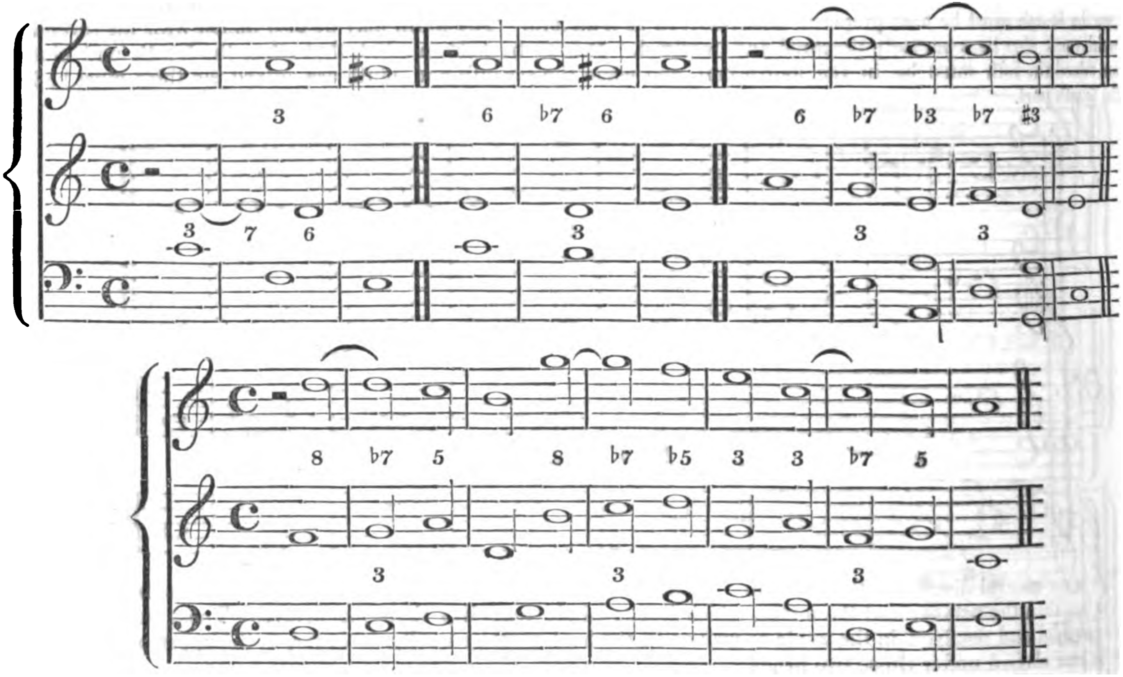


We may here remark, that the sharp seventh must have the major third on its resolution, otherwise the bass would rise a tritonus or descend a semidiapente, which are unallowable skips. For example, when the seventh is between F and E, it is resolved into a third major to avoid the tritonus. This seventh is resolved into a sixth major, the bass holding on. It may be resolved into a sixth minor, if the bass rise a semitone minor at the resolution.

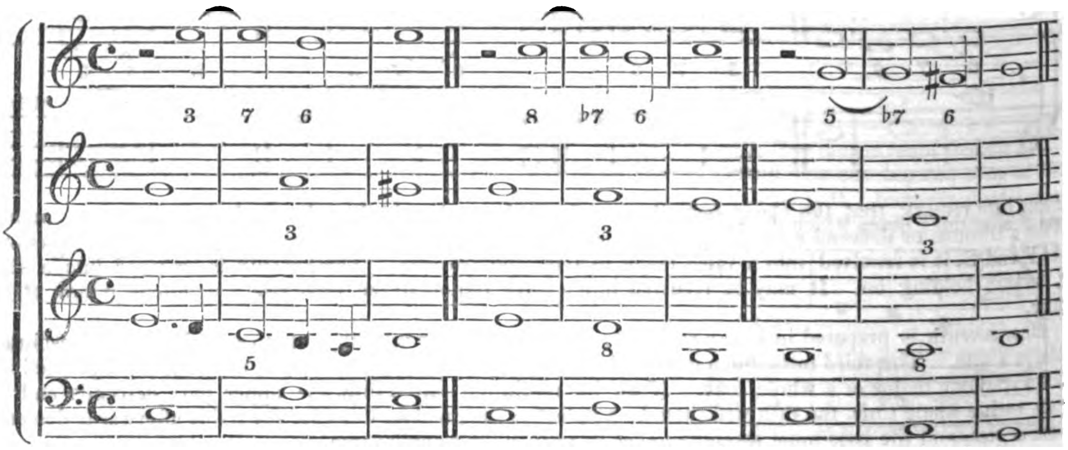
The minor seventh is prepared in a way similar to that of the major seventh, but it can only have its resolution in a third or a fifth. The third into which it is resolved may be either major or minor, as the discord respectively descends a semitone major or a whole tone. If on its resolution into a fifth, the upper part descends and the bass rises, each a whole tone, the fifth will then be a defective one, and in this case the treble afterwards descends one more degree, and the bass must ascend another to resolve the semidiapente.

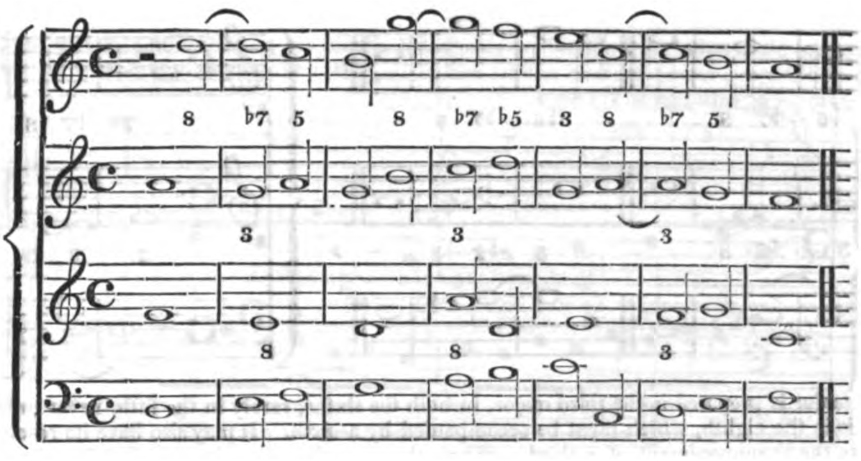


In three parts both the sevenths require that a third should be taken with them.

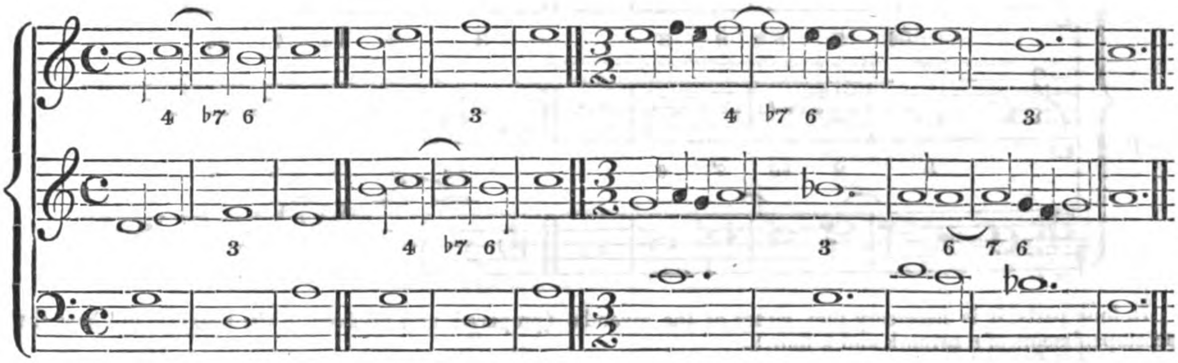


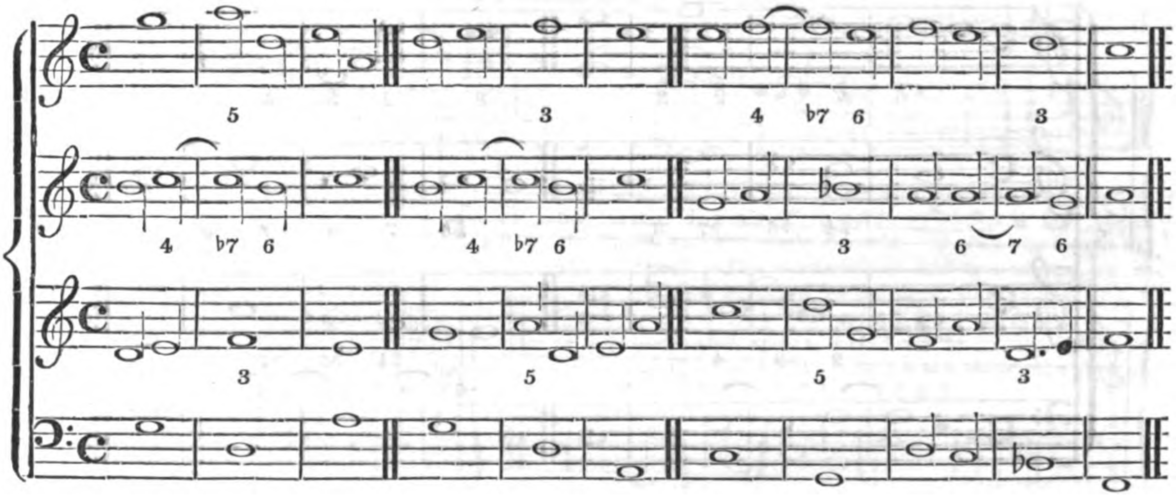
When four parts are used, both the seventh major as well as minor must have the accompaniment of the third and fifth. If the fifth does not come in, the preferable way is to double the note to which it is a seventh, and not to double the third.





The seventh minor may also, in three or in four parts, be prepared in a fourth, and finish, for variety's sake, in the third, instead of closing in the eighth with the part that had the seventh, but the third part must end with the fifth. All these modes of using sevenths will answer for cadences.

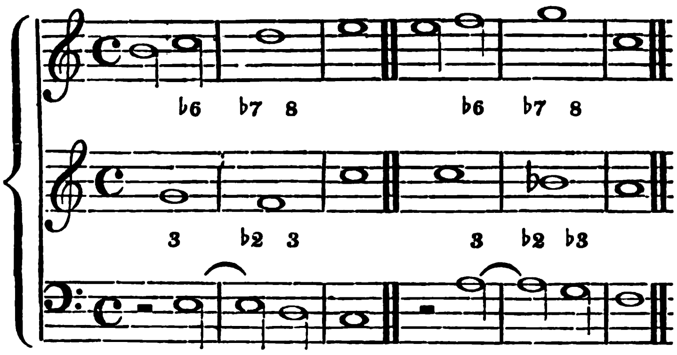


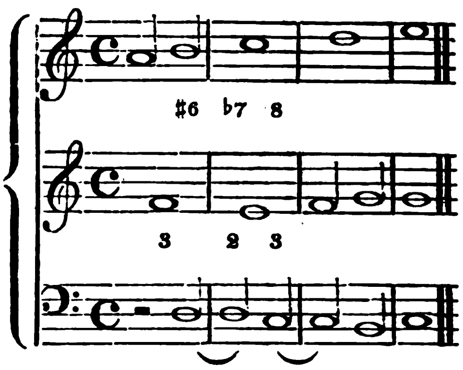


Prepared and resolved in the bass.

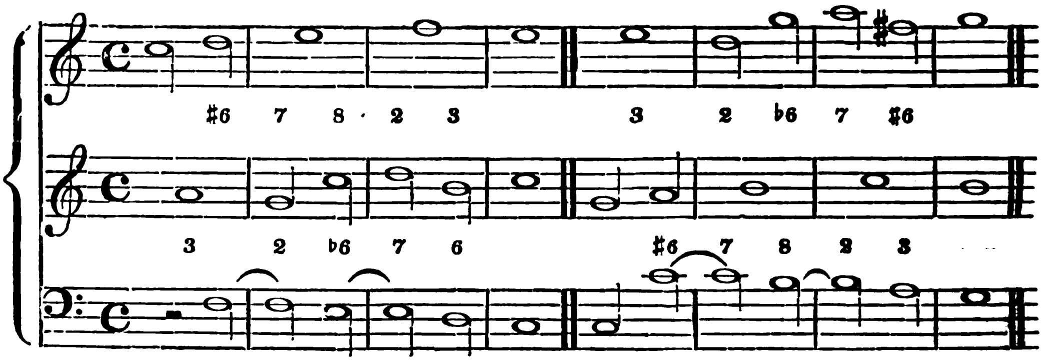
Sevenths, whose preparation and resolution are in the bass or lower part, must not be practised in less than three parts, inasmuch as they must have the accompaniment of the second or its replicate, which, it has already been observed, is the note which makes them discords. These sevenths are reckoned from the upper sound downwards to the lower, and are of two sorts, major, that is a semitone major, and minor, being a whole tone less than the octave, counting downwards from the lowest of the two adjoining notes in the upper parts.

The minor seventh is prepared in the third minor, the fifth, and in either of the sixths, never in the eighth, in order that two consecutive octaves may be avoided, because it can only be resolved in the eighth. If it be prepared in the sixth minor, the bass must be in E or A. If in the sixth major, the bass must be D or G, if it is the intention to keep in the natural scale.

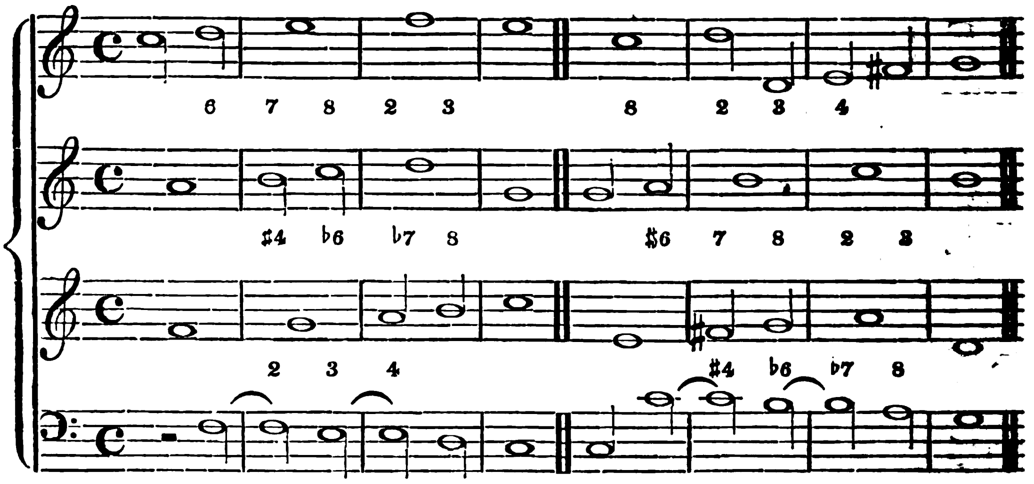




The seventh major is prepared in the third major, in both the sixths, rarely in the fifth, never in the eighth. Its best resolution is in the eighth, which must be accompanied by a sixth. It may also have its resolution in a sixth, which must have the accompaniment of a third. When the seventh major is prepared in the sixth major, the bass, if we intend keeping in the natural scale, must be B or E.



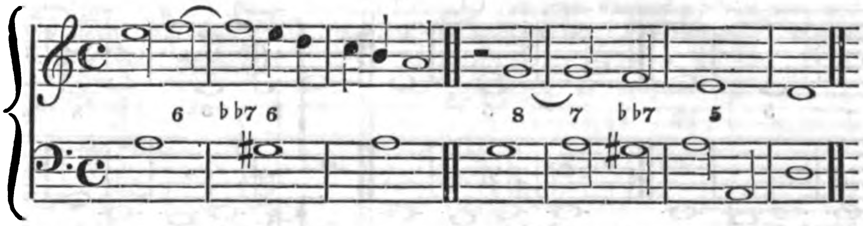
In four parts, it is necessary that either of the sevenths (prepared and resolved in the bass) should have the accompaniments of a seventh and a fourth.



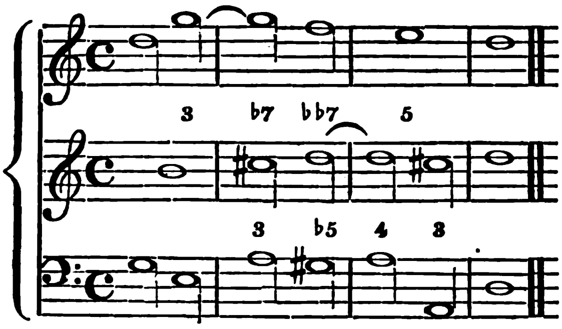
Diminished or extreme flat seventh.

We have now said as much as we think necessary in a Treatise of this nature, relating to the seventh when prepared and resolved in the bass. It may, however, be well to add, that besides these sevenths there is still another which, in ancient Music, was confined in its use to instrumental Music chiefly. It is called the diminished or extreme flat seventh. It is created when the natural flat seventh, prepared and resolved in the treble, is made still flatter by sharpening accidentally the note in the bass. The interval is such as that between G ♯ and F or between C ♯ and B ♭, &c., G and C being sharpened in the bass.

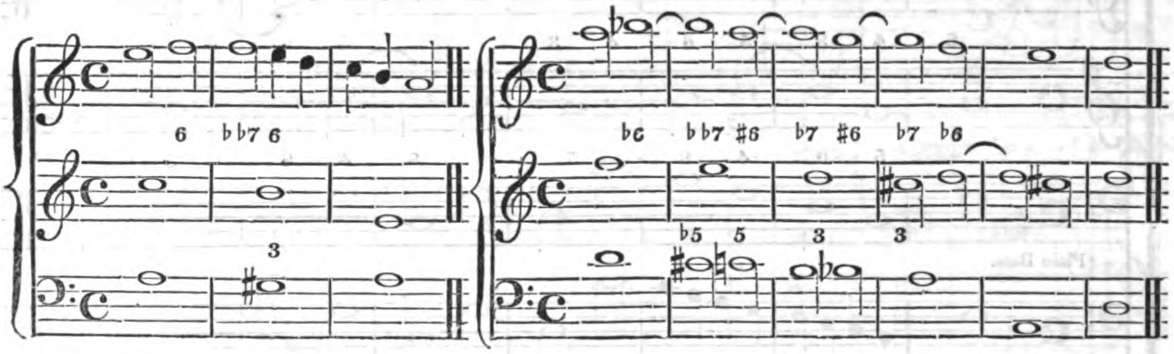
If we use the diminished seventh as a discord, its preparation and resolution must be in an upper part. It is best prepared in a sixth; into which concord it is again resolved by removing the accidental sharp in the bass on the resolution. The best resolution is into a major sixth, by the upper part descending only a semitone major; but it may also be resolved into a sixth minor, if the treble descend a whole tone on the resolution.



It is to be observed that we may use the diminished flat seventh without syncopation; it must then, however, be preceded by a concord and followed by a fifth or by a third. The natural flat seventh, when syncopated, may sometimes be resolved into the extreme flat seventh, which must afterwards be followed by more.

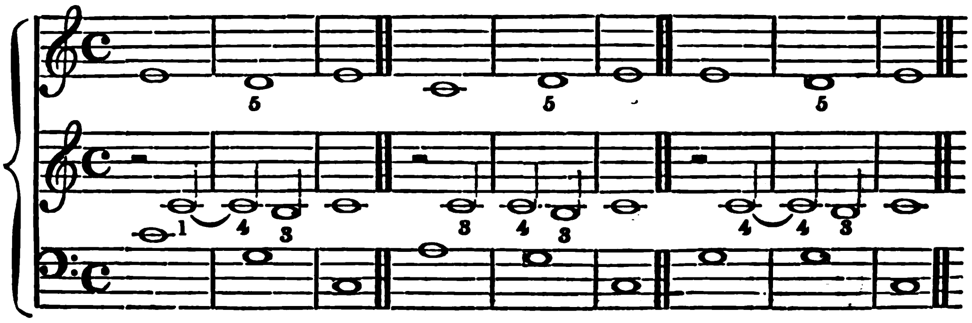


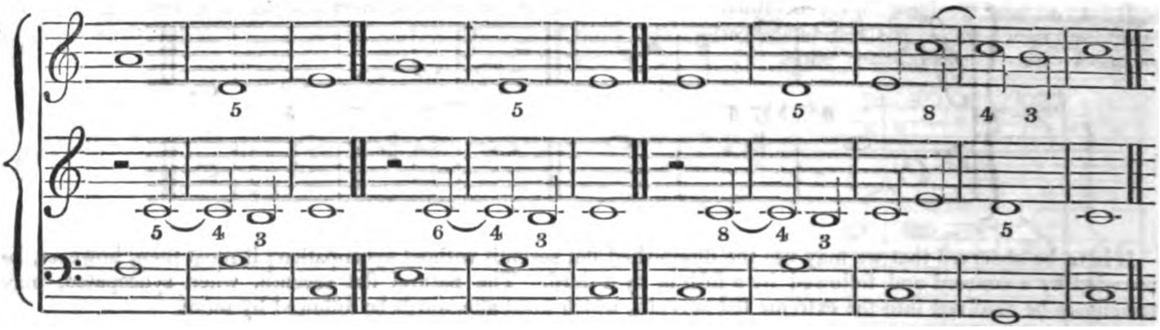
If the Music be of three parts, the accompaniment must be a third or a semidiapente. If of four parts, the third and semidiapente or flat fifth must be taken with it.

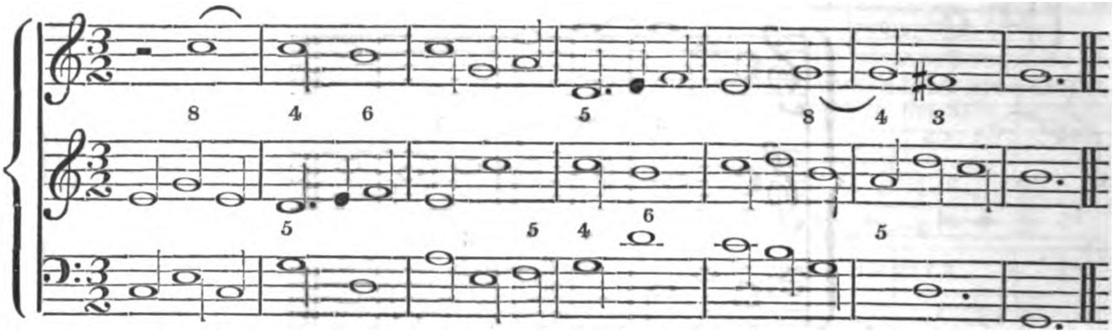


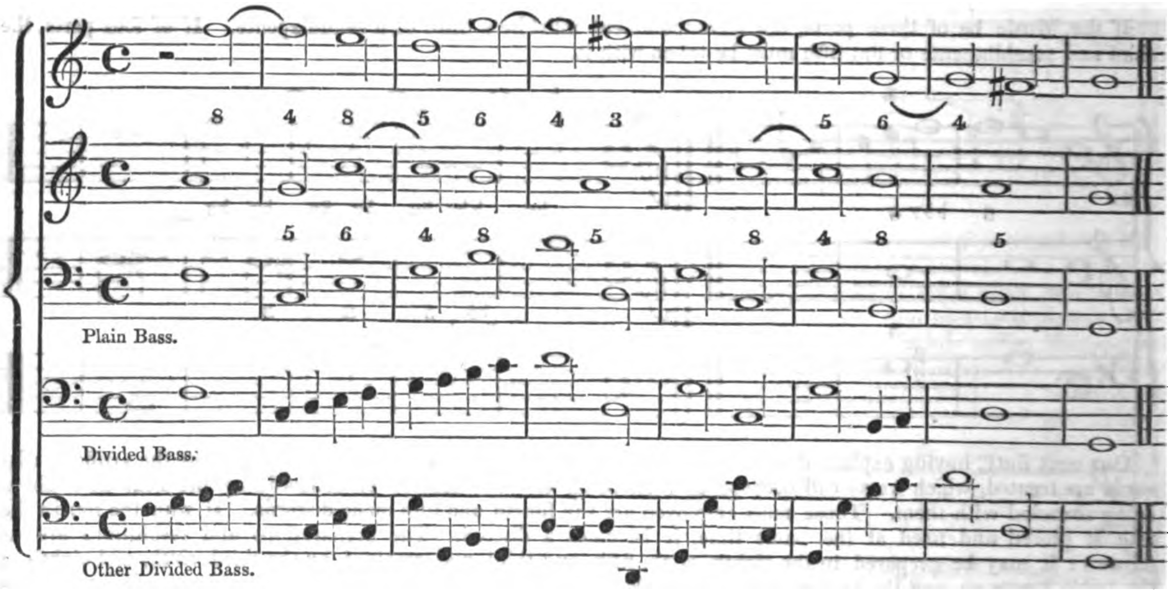
Artificial discords. Fourth

Our next duty, having explained the use of the natural discords, will be that of showing how the artificial discords are treated, which we so call because of their being created discords of concords by the next note above being sounded with them. Those most employed are the fourth and fifth made discords. If with the fourth the fifth is placed and used at the same time, it becomes a discord. The preparations and resolutions are as follows: it may be prepared in the eighth, sixth, fifth, and third, and resolved by the third, sixth, and eighth, if the treble keeps on, and the bass rises a fifth or falls a fourth, rises a third or falls a sixth, rises one degree or falls one degree. Or it may be similarly resolved if the treble falls one degree, and the bass keeps on or rises a fifth, or falls a fourth, or rises a third or falls a sixth. The resolution of it in an eighth is best when made on a divided bass.

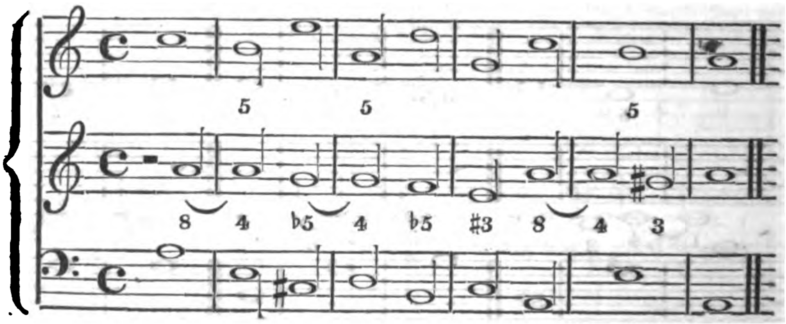




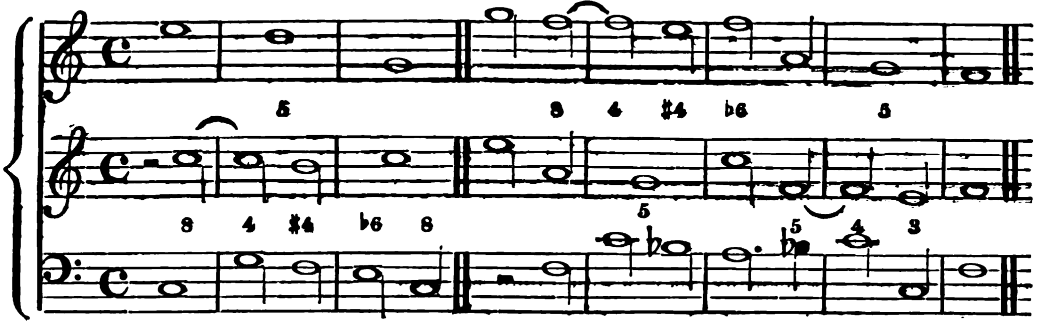




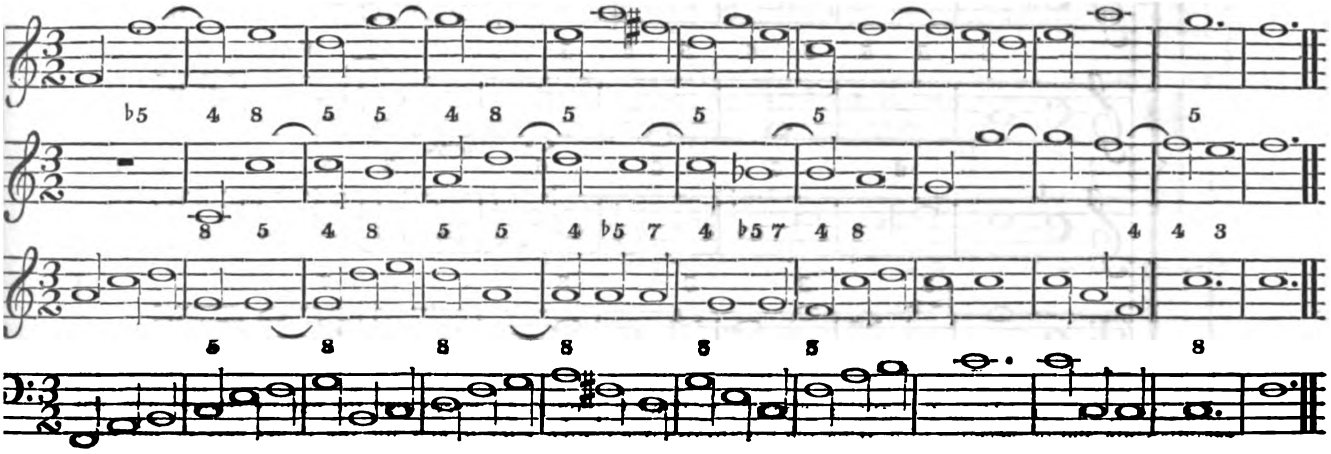
Besides the resolutions here given, the fourth may be resolved in the semidiapente, or false fifth, if the bass fall a third minor, and the discord descend a whole tone.



It may also be resolved in the tritonus, or sharp fourth, if the bass descend a whole tone and the discord a semitone major; but these false relations must be thereafter resolved as will be shown. The fourth is useful in cadences where there are many parts.

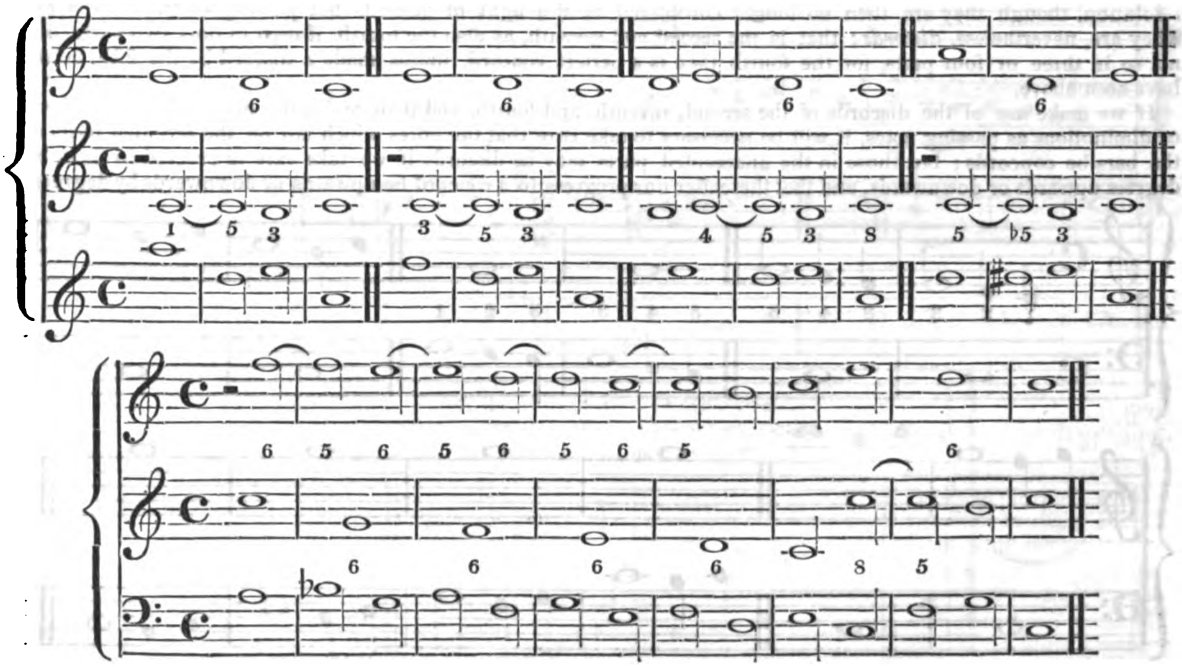


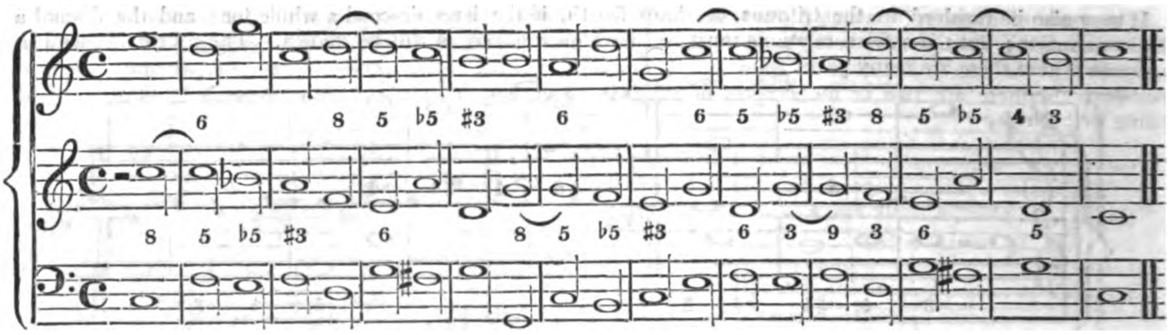
In four parts, the best accompaniment is the eighth.



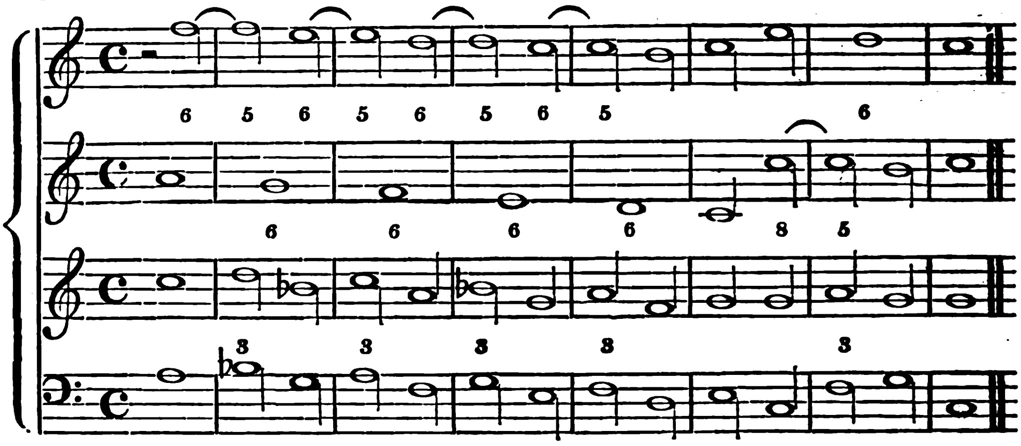
When the sixth is taken and struck with the sixth it becomes a discord. Its preparations and resolutions are as follows. It is prepared in the eighth, sixth, and third, and resolved by the third and sixth, if the treble keeps on and the bass rises a fourth or falls a fifth, or the bass rises one degree, or the bass rises a sixth or falls a third. And, also, if the treble falls one degree and the bass rises one degree, or it rises a sixth or falls a third.

Fifth as a discord.





In four parts, it is best to accompany this fifth with a third, as under:



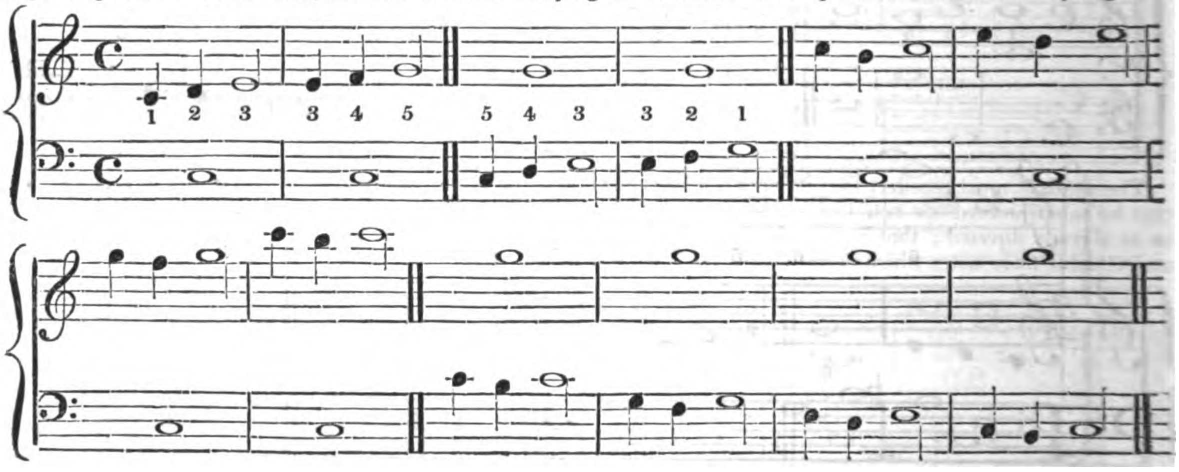
In closing our remarks on the artificial discords we think it proper to observe, that the natural resolution of the semidiapente, flat or defective fifth, is for the bass to rise one degree after it, and for the upper part to fall one, the parts thereby meeting in a major third.

The natural method of resolving the tritonus, or sharp fourth, is for the bass to fall one degree and for the upper part to rise one, whereby the parts meet in a minor sixth.

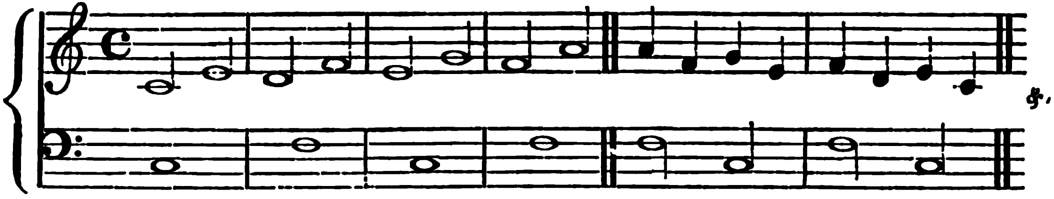
Discords by supposition.

In our remarks on discords we have hitherto confined ourselves to their mere preparation and resolution. But there is another way in which they may be and are constantly used without such regular preparation and resolution, though they are then no longer considered in the light of discords but *passing* or *transient notes.* They are, nevertheless, *discords;* that is the second and seventh, as also the fourth, if used in only two parts, but not so in three or four parts, for the fourth then is a perfect concord, unless made a discord by the fifth, as we have seen above.

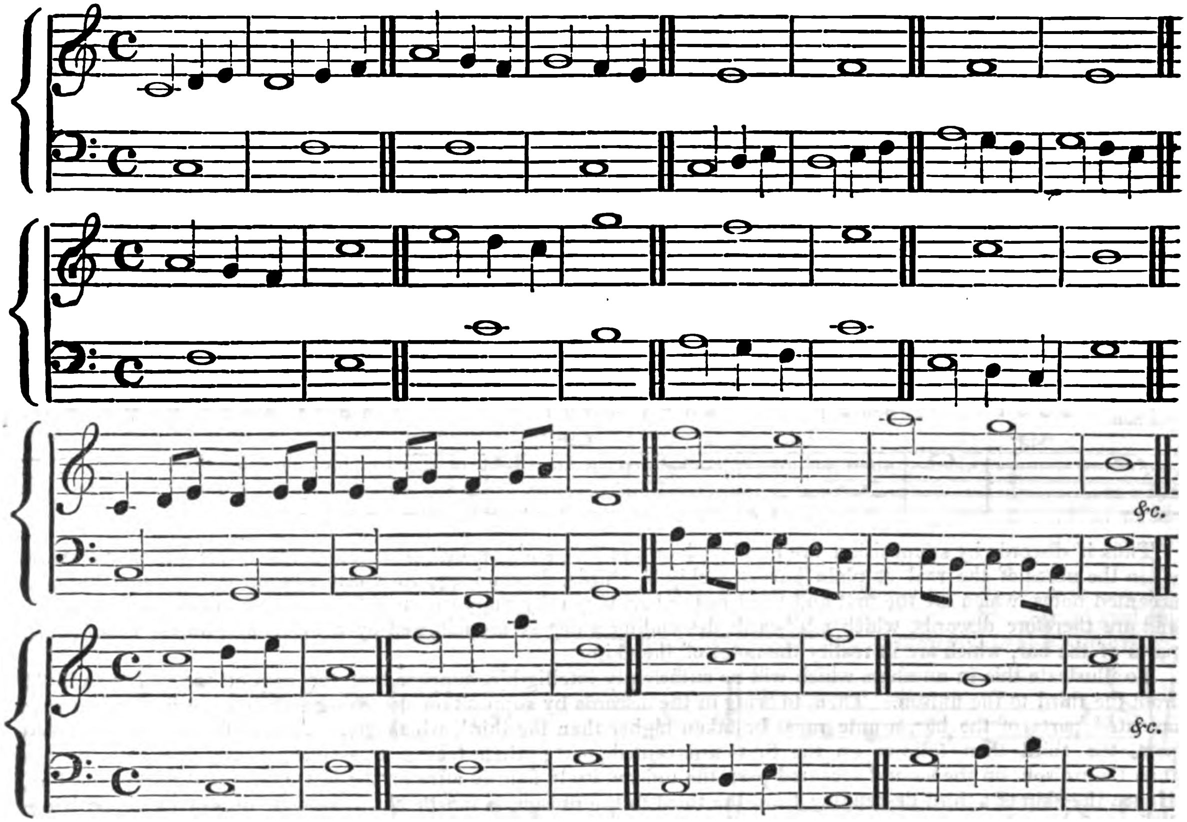
If we make use of the discords of the second, seventh, and fourth, and their replicates, or octaves in *divisions,* or diminutions as passing notes, it will be necessary to take care that the notes which fall on the accented parts of the bars be concords; but those in the unaccented parts may be discords if we take care to proceed to them by degrees upwards or downwards, and that thereafter our progress to a concord be upwards or downwards by degrees.



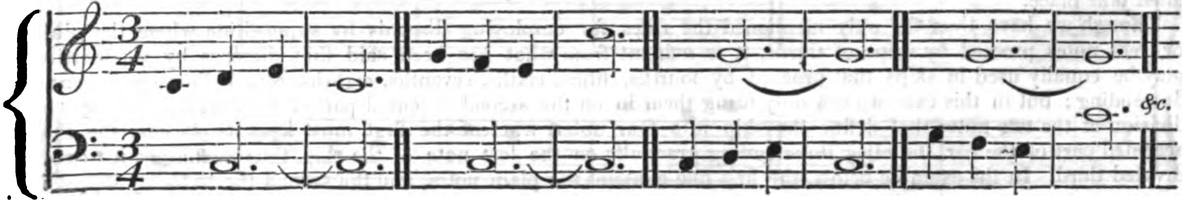
The mode of division by which discords are used upon the second accented part of the bar is called *supposition*, inasmuch as the discord thus brought in is supposed a note higher or lower than it really is; that is, we may suppose it at the degree the concord goes to. It is usually written in the treble or the bass, when in the plain counterpoint there are two or more notes of equal value or length in a bar that proceeds by skips of thirds rising or falling.



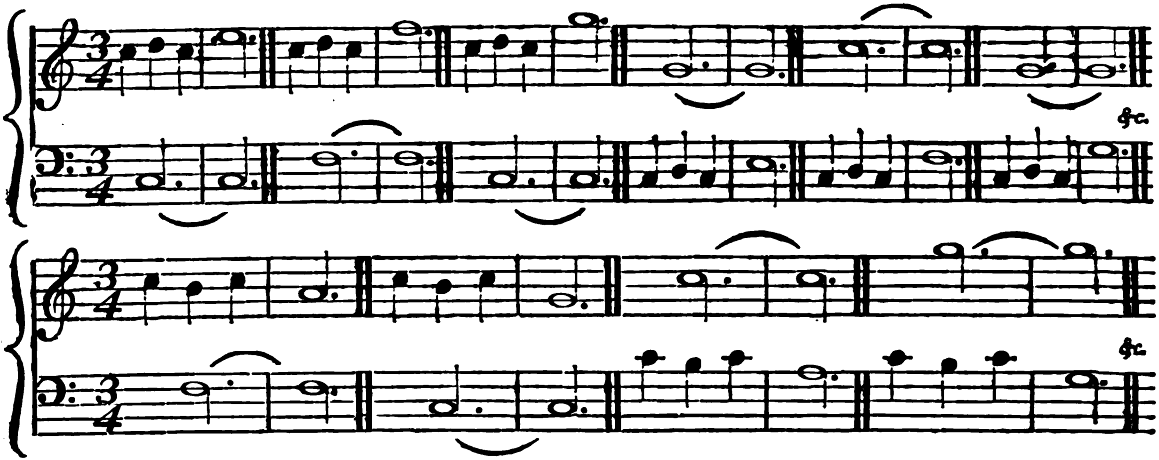
In skips of this nature only can discords be used on the accented part of the bar, that is, by breaking or dividing two notes that skip a third into three, the first note keeping its original length of two out of four parts of the bar, whilst the second note is divided into two of less length; by which method the first of the smaller divided notes is the discord, and will be on the third part of the bar, or second accented part; and the second or last divided note, which is the concord, will be on the fourth or last unaccented part of the bar. When the discord by supposition rises by degrees, or falls similarly to the concord, we can, if we proceed by a single degree, ascend or descend, as may suit us, to the note following the concord. If, however, the discord descend to the concord, and we wish to proceed by skip to the following note, it must be done by ascending to it; and if the discord ascend to the concord, we must, if we wish to go by leap to the note following the concord, descend thereafter



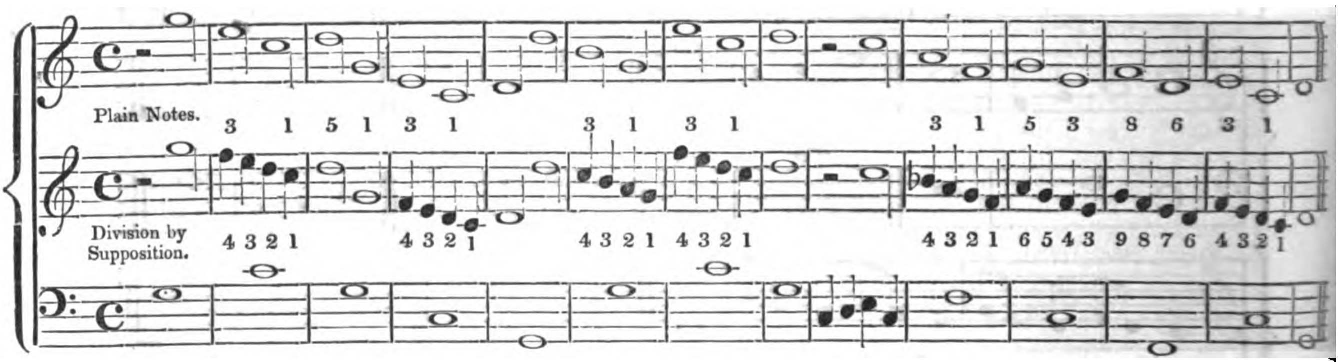
The student must recollect that no note can be the end or conclusion if a discord by supposition precede it, but that he must proceed one note further beyond it: if gradually, either upwards or downwards; if by a leap, it must be as already directed; that is, if a skip is made after three notes which ascend gradually, it must be descending, and if after three notes which descend gradually, it must be ascending.



And here it is right to notice with respect to those divisions which touch a discord after a concord, and thereon immediately return to the concord that was struck before the discord, that if the discord ascend by a single degree from the concord, and then by falling a single degree return to it, we must then skip upwards if we wish to go by a leap to the note that follows the concord. If, however, the discord fall a single degree from its preceding concord, and then by rising a single degree return again to it, we must skip downward if we are desirous to go by leap to the note that follows the concord.



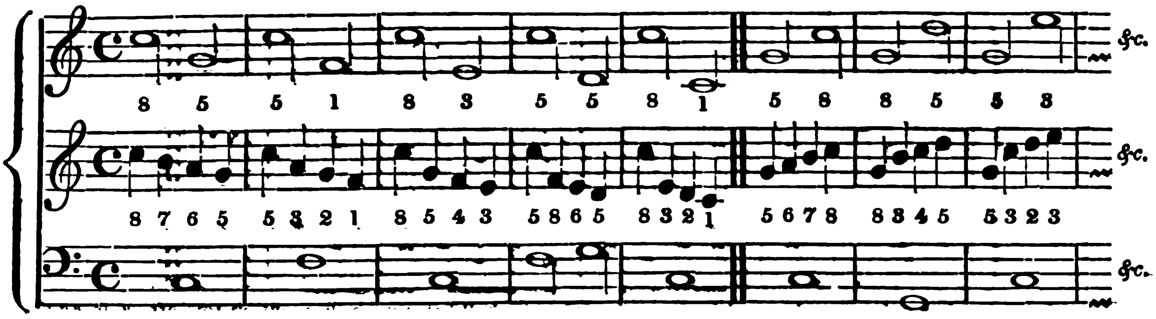
Discords by supposition may be used in the first half of the bar as well as in the second half, taking care that if we use them in the first accented part of the bar, they must also be used in the second half, and only in descending. This method is used in basses that sing as a treble part, and is of importance in bass instrumental accompaniments.

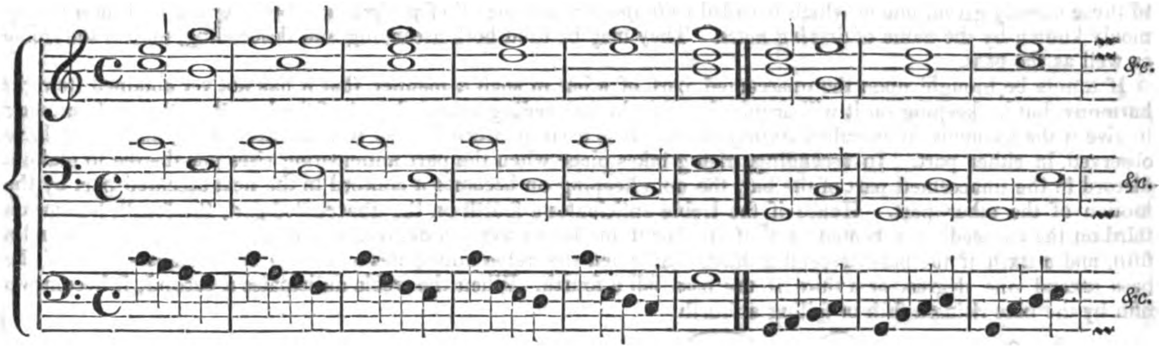


Thus if discords by supposition are employed on the first and second accented parts of the bar, it must be when the notes of the real or plain harmony skip by thirds, descending; in which case, in this division the two accented notes, which are the first and third in the bar, begin by supposition a degree higher than the real notes and are therefore discords, which afterwards descending a degree are followed by the concords on the unaccented parts of the bar, which are in reality the notes of the skip.

To illustrate this in numbers which will be sufficiently intelligible, suppose that the skip of the real sounds is from the third to the unison. Then, to bring in the discords by supposition as passing notes on the first and second accented parts of the bar, a note must be taken higher than the third, which gives a fourth for the first accented part, the third then follows on the first unaccented part; then taking a second, being one note higher than the unison on the second accented part, the unison itself follows after on the last unaccented part of the bar. Hence the skip of a third descending from the third to the unison, is fourth, third, second, unison by supposition. If from the fourth to the second, it must be fifth, fourth, third, second. From the fifth to the third, it makes sixth, fifth, fourth, and third. From the sixth to the fourth, we have seventh, sixth, fifth, and fourth. From the seventh to the fifth, it will be eighth, seventh, sixth, and fifth. And from the eighth to the sixth, we must place ninth, eighth, seventh, and sixth. It is hardly necessary to state that with the replicates or octaves the same arrangements must take place.

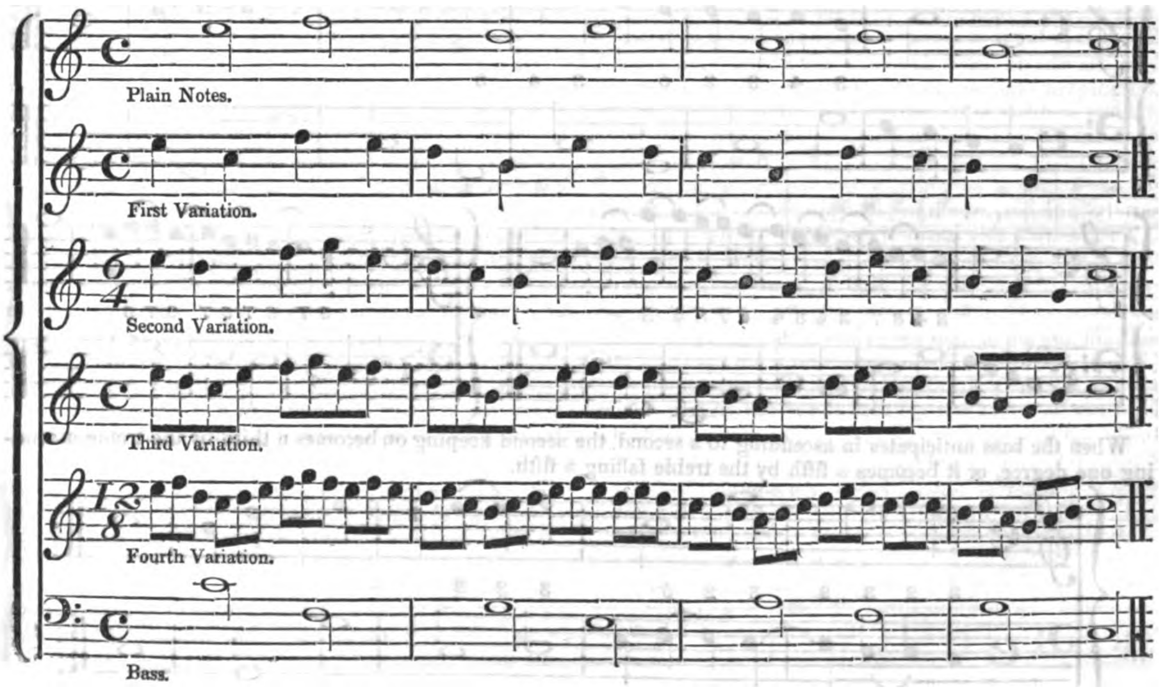
Though we have thus far only mentioned the rules for employing discords by supposition where the plain or real notes proceed by skips of thirds, it is evident from what has been said that discords by supposition may be equally used in skips that proceed by fourths, fifths, sixths, sevenths, eighths, &c., both ascending and descending; but in this case we can only bring them in on the second accented part of the bar, and that by the division of the two notes that define the skip into four notes, whereof the first must keep its place on the first accented part of the bar, the other three ending gradually on the last note of the skip, thus making as it were a divided third. In the example below, the first line contains the plain notes, and the second the treble by supposition; and in the second appended example, the second line contains the plain bass notes, and the third the bass by supposition.



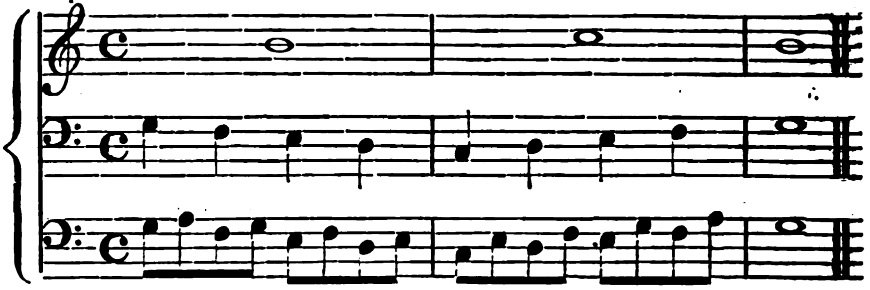


In explanation of the above, take the skip of the eighth descending to the third, which is a skip of a sixth, then by the rule we get eighth, fifth, fourth, third. Or if the skip of the sixth be ascending, as from the fifth to the tenth, we get fifth, eighth, ninth, and tenth. By these examples we see that the supposed discord is on the second accented part of the bar. Thus we may use discords by supposition in any given leaps; they are, however, as will immediately occur to the reader, suited to instrumental and not to vocal music. But we have said enough to give an insight into that kind of division which is called supposition.

Variation. Variation is the subdivision of a division. It is effected by dividing a note or sound into two, three, or more notes, so that that note is always retained upon which the variation is made, making it the first note of the division, and then proceeding to make two, three, or more notes upon it without changing the air, that is, the melody or harmony of the note upon which the variation is made.



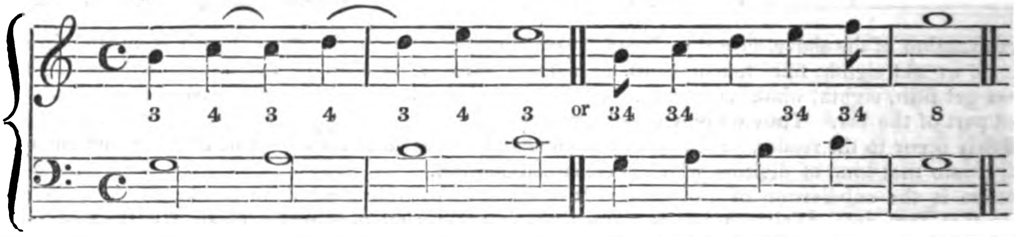
Variation may take place either in the bass or treble, but it should not be carried to excess in the bass, especially in vocal Music; and the ear, moreover, does not so well distinguish and separate quick progressions in low tones. We subjoin an example of variation in the bass.

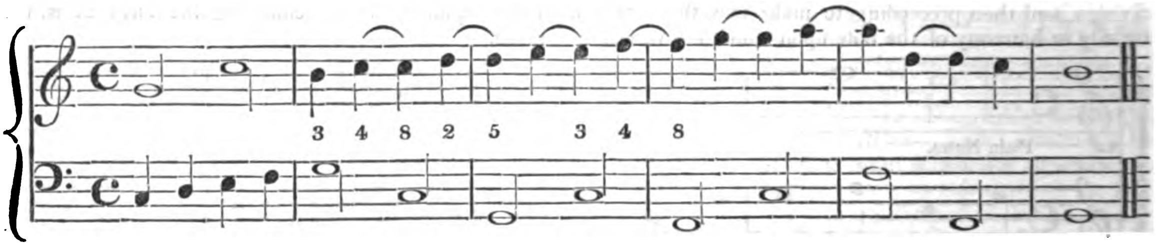


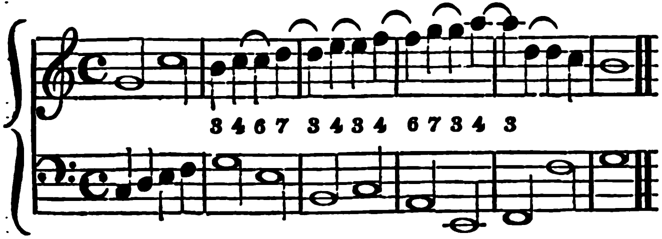
Discords, as passing notes, may be used in several ways; we shall however only mention two others in addition to those already given, one of which is called *anticipation* and the other *postposition*, but they are both more commonly known by the name of *driving notes*. They may be used both ascending and descending, and in the treble as well as the bass.

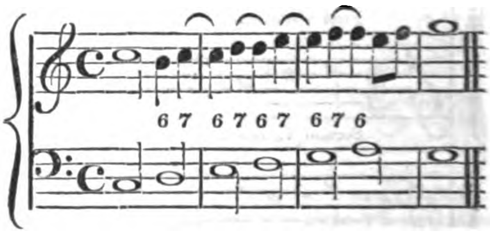
Anticipation.

If a note be brought upon the unaccented part of a bar in such a manner that it has not yet obtained its right harmony, but by keeping on it will acquire it upon the succeeding accented part of the bar, the other note moving to give it the harmony, it is called *anticipation*. It is used in ascending as well as descending, and as we have observed, in either part. In ascending, rising takes place when the part anticipating rises one degree to make a discord in the unaccented part of the bar, the note keeping on becomes a concord in the next accented part by the motion of the other part. Hence if the treble anticipates a fourth on the unaccented part, the fourth becomes a third on the succeeding accented part of the bar if the bass ascend a degree, or an eighth, if the bass descend a fifth, and a sixth if the bass descend a third. So when the treble anticipates a seventh it becomes a sixth if the bass ascend one degree, or a third if the bass fall a fourth. When the treble anticipates a second, it becomes a fifth by the bass rising a fifth or falling a fourth.

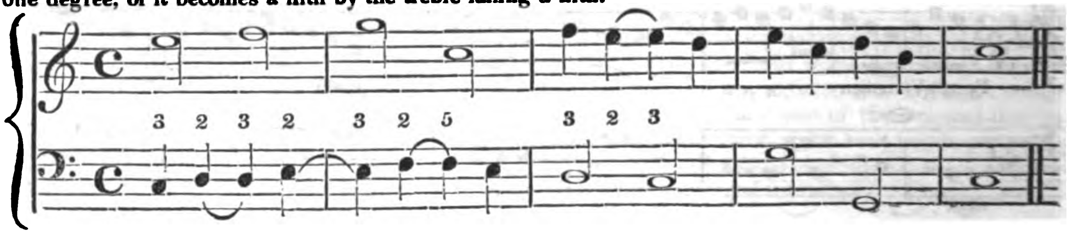




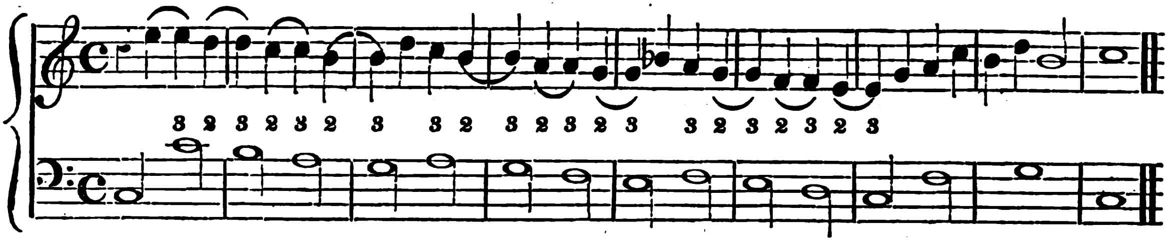




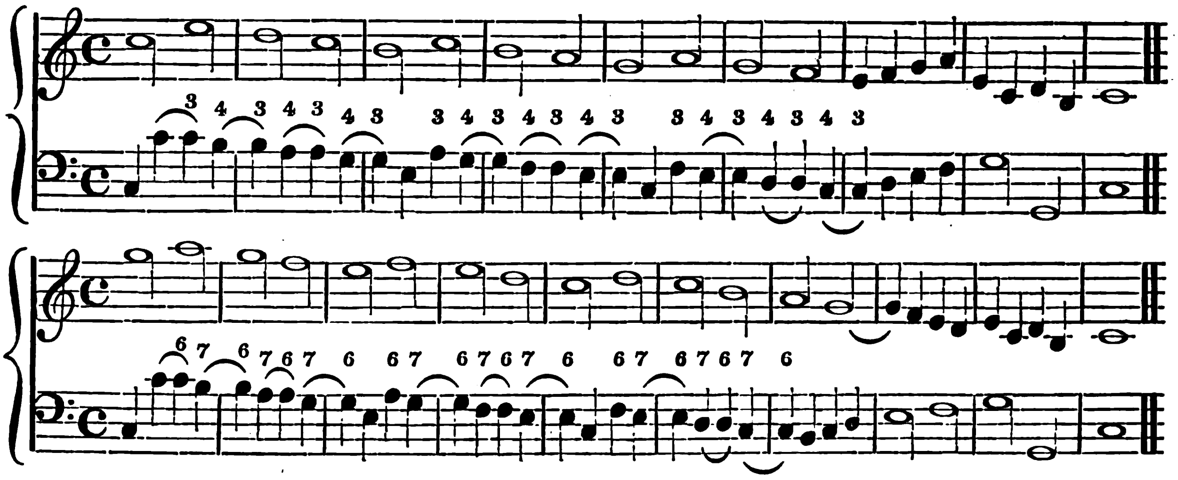
When the bass anticipates in ascending to a second, the second keeping on becomes a third by the treble ascending one degree, or it becomes a fifth by the treble falling a fifth.



When anticipation is used in descent, the part which anticipates falls one degree to a discord in an unaccented part of a bar, and that holding on becomes a concord in the succeeding accented part by the other part moving. Thus, suppose the upper part to anticipate, by descent, one degree to a second, that second becomes a third by the bass descending one degree, or a unison by the ascent of the bass one degree.



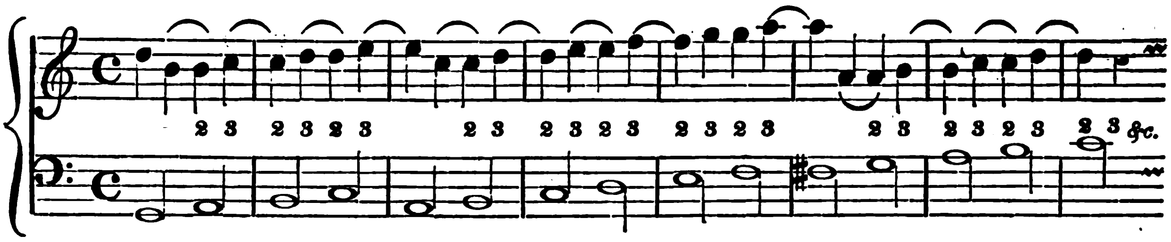
If by descent one degree the bass anticipates to a fourth, the fourth becomes a third by the treble falling one degree. If by descending one degree to a seventh the bass anticipate, the seventh becomes a sixth by the descent of the treble one degree.



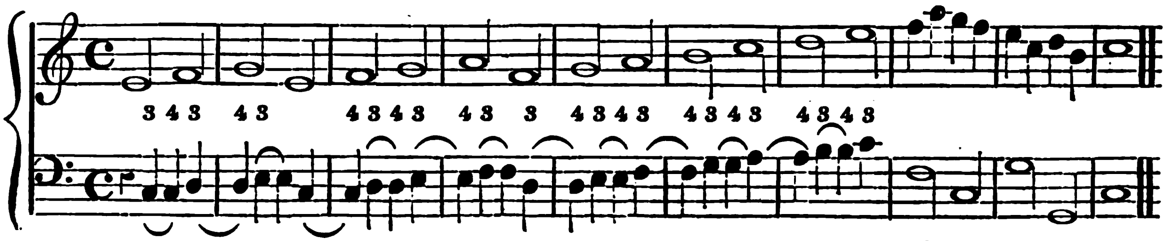
Though there be many other ways in which anticipation may be effected, both ascending and descending, we do not think it necessary to give any more examples. The student by practice on the discords cannot fail of finding them out and using them, if what has been premised be well understood.

Postposition.

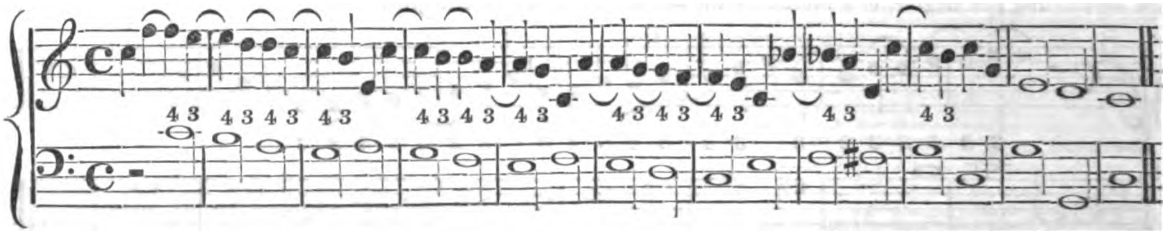
If we place a discord on the accented part of the bar, and it be followed by a concord on the next accented part, such position of the discord, without that preparation and resolution which the laws of harmony require, is called *postposition* or *retardation* of the harmony. It is effected in the upper part when a discord taken on the accented part becomes a concord on the succeeding unaccented part by rising one degree, the note in the bass keeping on. A second thus becomes a third.



It takes place in the bass when that having a third on it in the unaccented part of the bar and holding on the treble has a fourth as a discord upon it in the following accented part of the bar, which, by the ascent of the bass one degree whilst the treble keeps on, afterwards becomes a third.



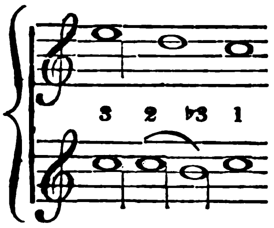
In descending, *postposition* takes place when the discord on the accented part of the bar is made a concord on the following unaccented part, the bass holding on and the treble descending one degree. Thus a fourth becomes a third.



Cadences.

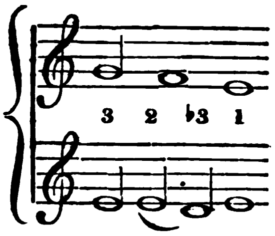
A cadence may be defined as the conclusion of a strain, or of the parts of it in places of the composition dividing it as it were into so many clauses or periods. It is in short, as the term expresses, the fall or conclusion of a series of harmony which the ear seems naturally to expect as its termination.

There are two sorts of cadences *perfect* or *final*, and *imperfect* or *middle*. To make the former three different modes may be adopted. We shall commence by examples in two parts only, in which the cadences should always end in the unison. It is effected by a minor third in the penultimate note, which afterwards falls a whole tone or semitone major to the unison, the last note of the cadence. If it descend a whole tone, it is necessary that the under part should rise a semitone major to meet it in the unison. But when the minor third in the upper part falls only a major semitone-major to the cadence note, the bass rises a whole tone to meet it in the unison. The semitone major may be natural or accidental by means of a sharp or flat. The following is a cadence in two parts in the key of C in the unison.



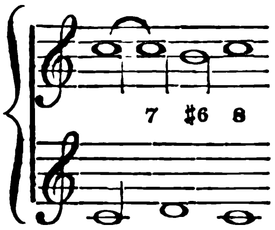
Here the second, which is a prepared discord, appears upon the antepenultimate note, and is resolved by a minor third upon the last note but one, upon which the upper part falls a whole tone, the bass at the same time ascending a semitone major, whereby the cadence is completed.

The next example is in the unison on E,

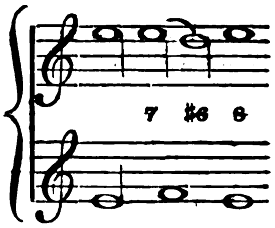


in which the difference between it and the preceding example arises from the upper part descending a semitone major, while the lower part ascends a whole tone to the unison. This turning the cadence in E differs, moreover, from that of the other keys, inasmuch as the whole tone takes the place of the semitone, and the semitone that of the whole tone in the others.

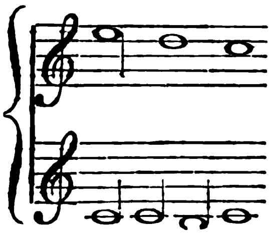
The remaining perfect cadence in two parts, is in the octave or eighth, and is best by contrary motion and as gradual as may be. In this the penultimate must be a major sixth, namely, the note in the upper part which ascends to the final or cadence note by a whole tone or semitone major. When the upper part rises a whole tone, the bass descends a semitone major. If, however, it ascends a semitone major, the bass descends a full tone, in order that the two parts may close the cadence in the eighth. Thus,



There are, however, two ways of making a cadence on the eighth, whereof that which is above given is the best if two parts only be employed. The example shows that the seventh here, after preparation, is struck on the antepenultimate and resolved into a major sixth in the following note, upon which the upper part rises a major semitone, the bass descending a whole tone, which leaves the parts an octave apart and closes the cadence. The next example of the cadence is on the eighth in E in two parts, and as follows:

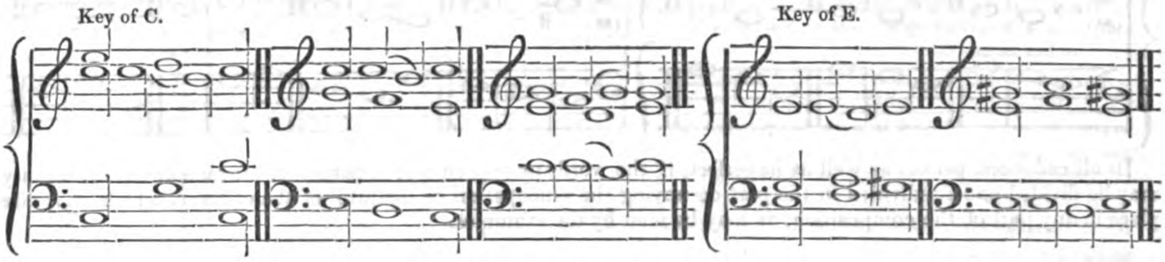


It is only necessary to remark upon this cadence as on that in the unison, that it is in the key of E, and we have a semitone where the other keys have a whole tone, and the whole tone where they have a semitone. The remaining method of taking the cadence on the eighth, which in truth is similar to the cadence in the unison, is as follows:



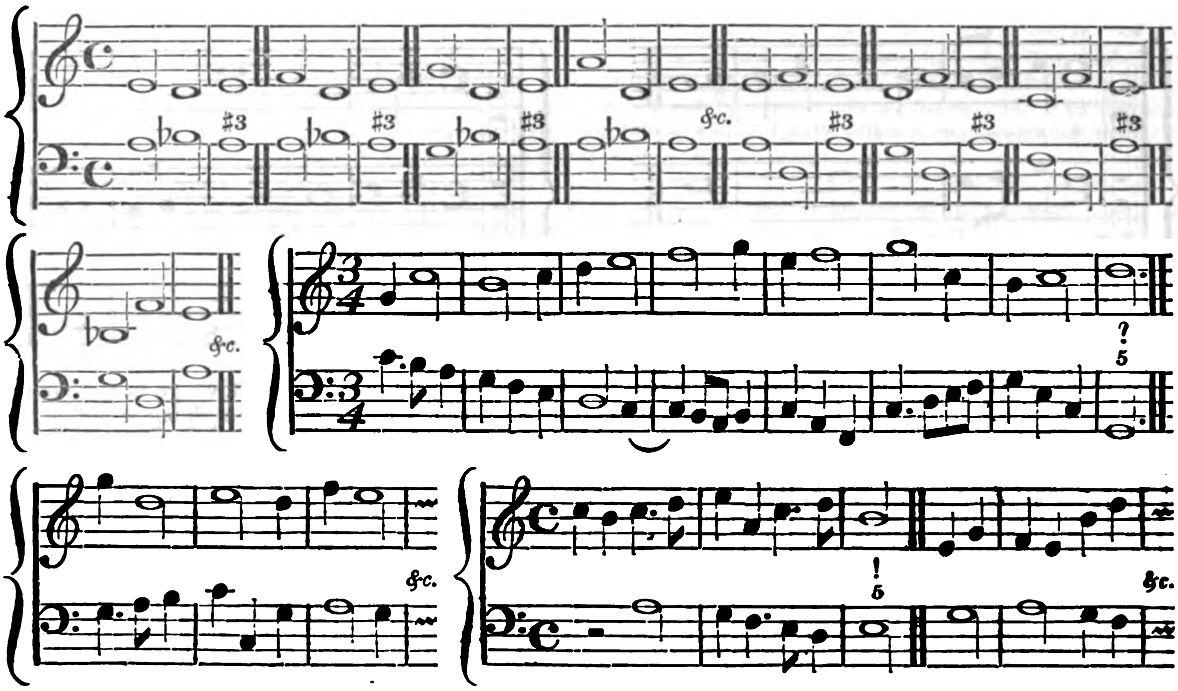
in which, comparing it with that cadence, it differs only in the parts being a tenth instead of a third apart.

We now subjoin three cadences in C and two in E, in which they are exhibited with the best harmony on the last note of the cadence.

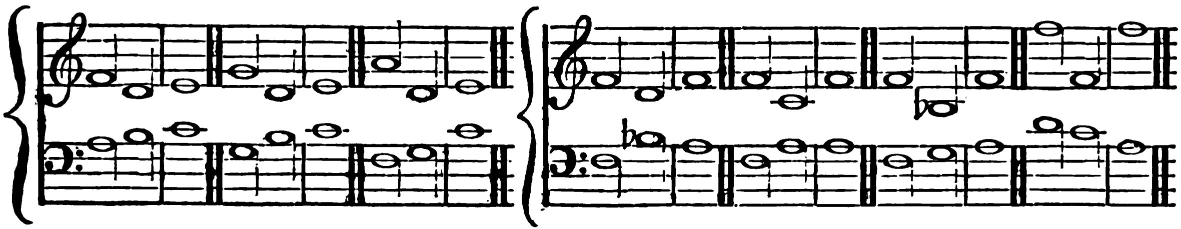


The mode of making these in four parts and accompanying the discords in them, has been already laid down. The first of the above cadences is sometimes called the grand cadence. It closes in the unison or eighth, and differs from the other, inasmuch as the last note but one must be a major third, which then rises a major semitone, whilst the bass falls a fifth or rises a fourth to the cadence note. If the bass rise a fourth, it is a cadence in the unison, if it fall a fifth, it is a cadence on the eighth. It should not be used in two parts because of the skip to the last note in the bass, which is better where there are more parts. These cadences in the unison and the eighth seeming to answer to the full stop in writing, appear thence to have acquired the name of final cadences.

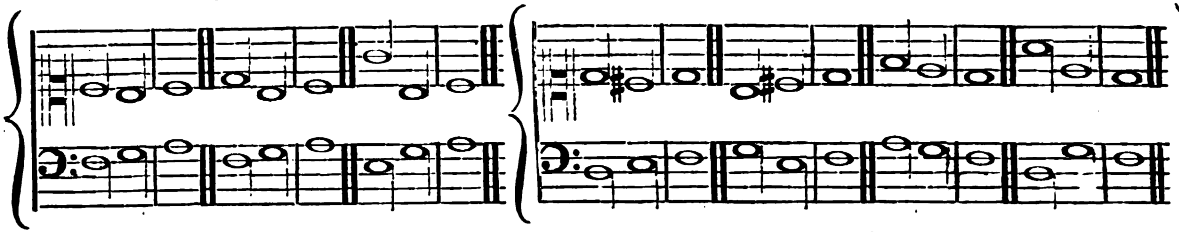
The imperfect, or middle cadences, are so called from their being used in the middle of a strain where it is not the composer's intention to close it finally. The fullest of them is on the fifth, seeming to answer not only to the colon and semicolon in writing, but also to notes of admiration and interrogation ; when seeming to denote the latter, the upper part rises to the cadence note, which is a fifth. A melancholy expression is produced by its rising, and the contrary by its falling to the cadence.



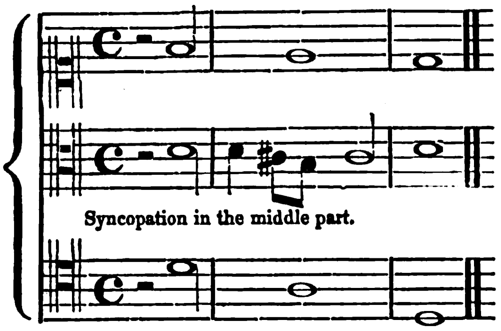
The next in order as to excellence are middle cadences in the major third or minor sixth; they are a species of weaker interrogation when the upper part rises to the cadence. They both rise and fall to the last note of the cadence.

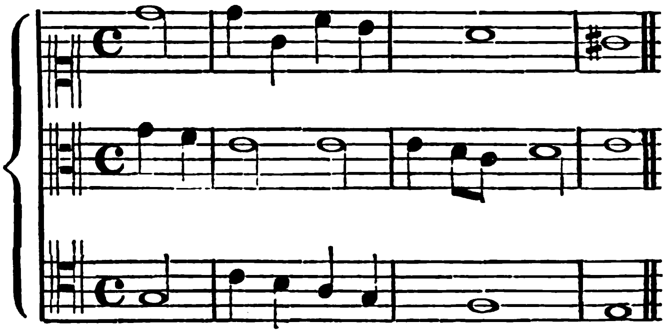


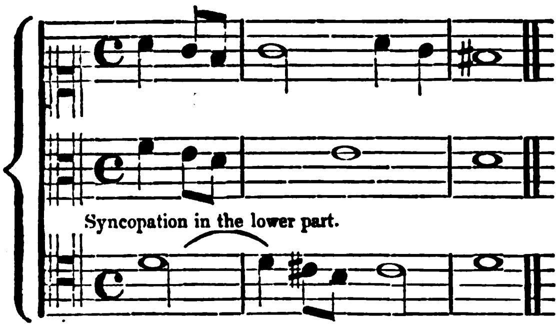
The middle, or imperfect cadences, which are considered the worst, are those in a minor third or major sixth.

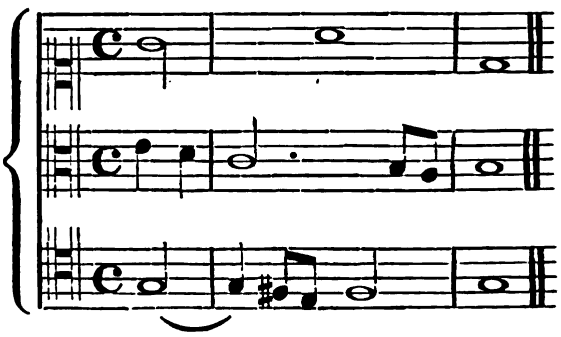


In all cadences, perfect as well as imperfect, if the words or sequence of a particular movement require it, they may be divided and subdivided in the part occupying the syncopation or ligature of the cadence, which may take place in any part of the composition, as may be seen by the examples.

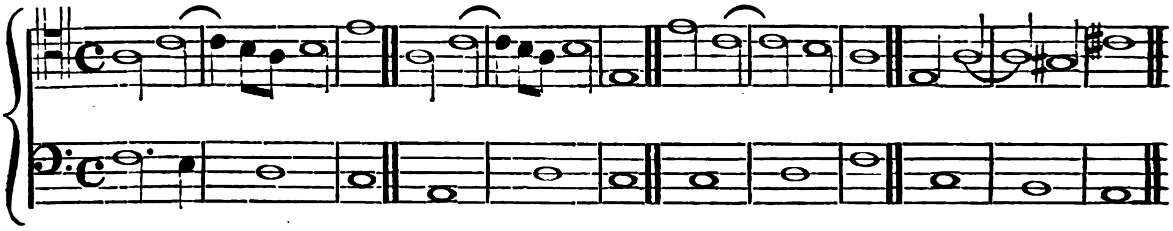








A cadence is *avoided* when, after having prepared and resolved the discords preceding it, we go to some other note than that on which it ought to conclude and thus break it off, and it is then called the *flying*, *avoiding*, or *deceptive cadence.*

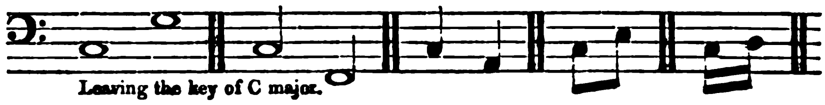


The reader, we presume, will be able, from what has been already given, to form examples for his own study; we shall therefore leave this part of the subject to proceed to the following important section.

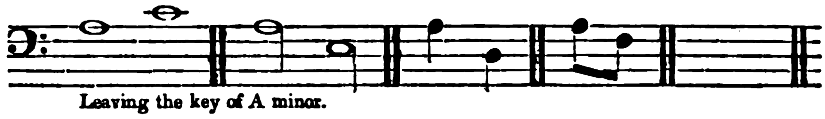
Modulation.

When in the course of a melody the key note is changed and the original scale altered by the introduction of either a sharp or a flat, such change is called *modulation.* More properly speaking, it is the method of keeping in and using the principal key; but it is more generally received in the sense of the definition we have given. As the key is the result of harmony, from that harmony also arise the laws of modulation. These are simple enough in their nature, but difficult to follow. They are, if you desire to keep in the key, first, to use all the different sounds of the scale as much as possible, uniting them in a good melody, and dwelling principally on those which carry the essential chords. Or in other words, the chords of seventh and key notes will be frequently wanted, but in different forms and by varied methods in order to avoid a monotonous effect. Secondly. To take cadences or pauses on these two chords only, or at furthest on that of the fourth of the key. Thirdly. Never to alter the scale, because if a sharp or flat is introduced which does not originally belong to it, or one is taken from it, the key is then quitted.

In order to pass from one key to another, it is necessary to consider the analogy or relation between the two



Leaving the key of C major.



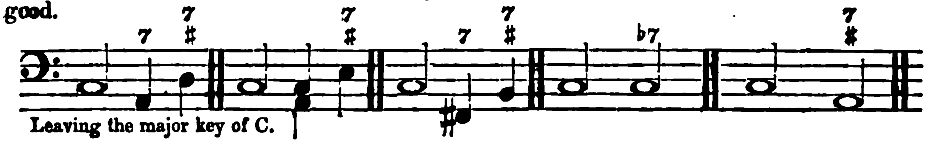
Leaving the key of A minor.

These immediate modulations show the method of passing by following up the rules into the most distant keys, and of returning to the principal key of which we are never to lose sight. But it will not be sufficient to know the routes we are to take without knowing the way to their entrance.

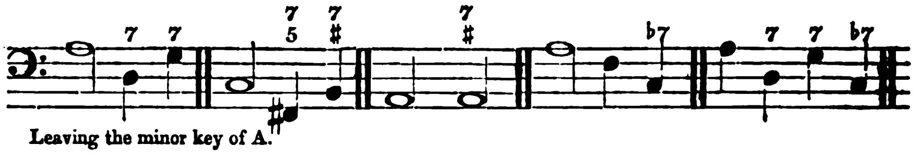
On this head we shall give a summary of the precepts. In a given melody, in order to introduce the modulation desired, it is only necessary to hear the alterations it causes in the notes of the key left to suit them to that whereto we proceed. Suppose we are in C major, it is only necessary to strike an F sharp to indicate the key of the fifth, or a B flat to indicate that of the fourth. Then go over the essential chord of the key into which you have entered, which, if well selected, will give your modulation a regular and pleasing effect. In harmony there is considerably more difficulty, for as it is necessary that the change of the key should appear in all the parts at the same moment, we must keep our eyes on the melody and harmony conjointly in order to avoid two different modulations. Huyghens has remarked, that the disallowance of consecutive fifths in harmony is founded on this principle. In truth, one can scarcely, in two parts, introduce consecutive fifths without finding that he has been modulating in two different keys.

To introduce a key there are many who say it is sufficient to give the perfect chord of that key, and that it is indispensable to it; but it is clear that the key can only be determined by the sharp seventh or the fifth, which must be heard in proceeding to the new modulation. A good rule seems to be that the seventh should always be prepared in it, at all events the first time it is heard; but in all the allowable modulations this rule is not always practicable, and we always shall find the modulation good if the fundamental bass proceeds by consonant intervals, if we keep that harmonic tie which in a chord preserves one or more of the notes used in that preceding, if we regard the analogy or relation between the keys, and if we avoid false relations. Composers, moreover, lay it down as a rule not to change the key, except after a perfect cadence, but this is rarely attended to.

All the methods of passing from one key to another, are five for the major and four for the minor keys: if any other be used than is indicated in the subjoined diagram, unless it be an enharmonic modulation it cannot be considered good.

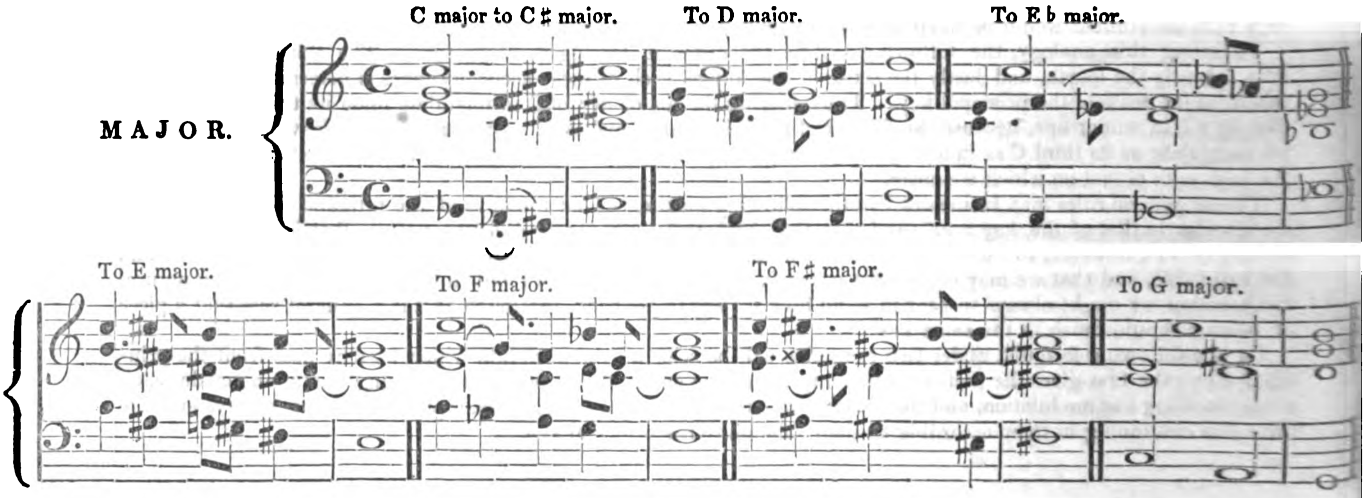


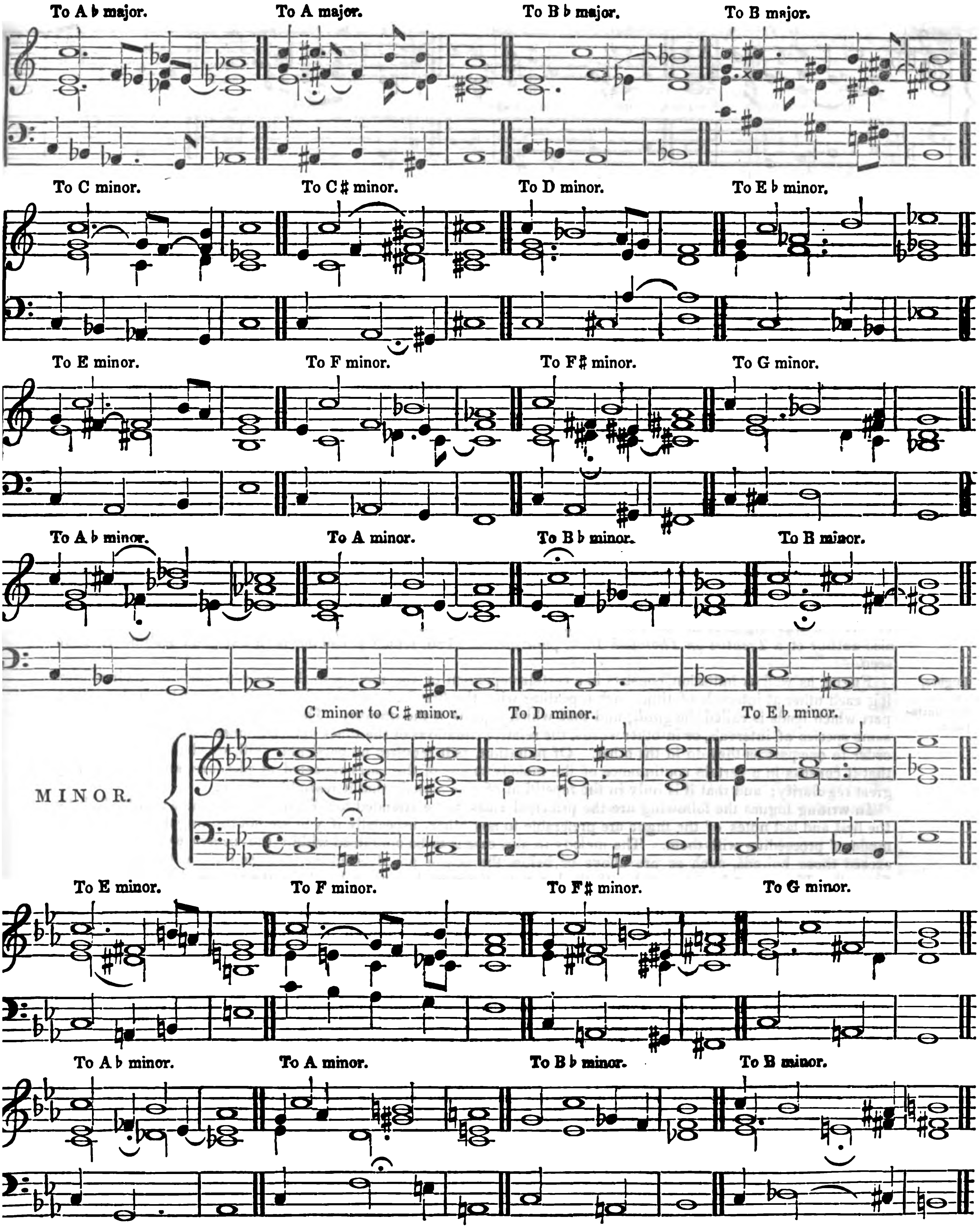
Leaving the major key of C.

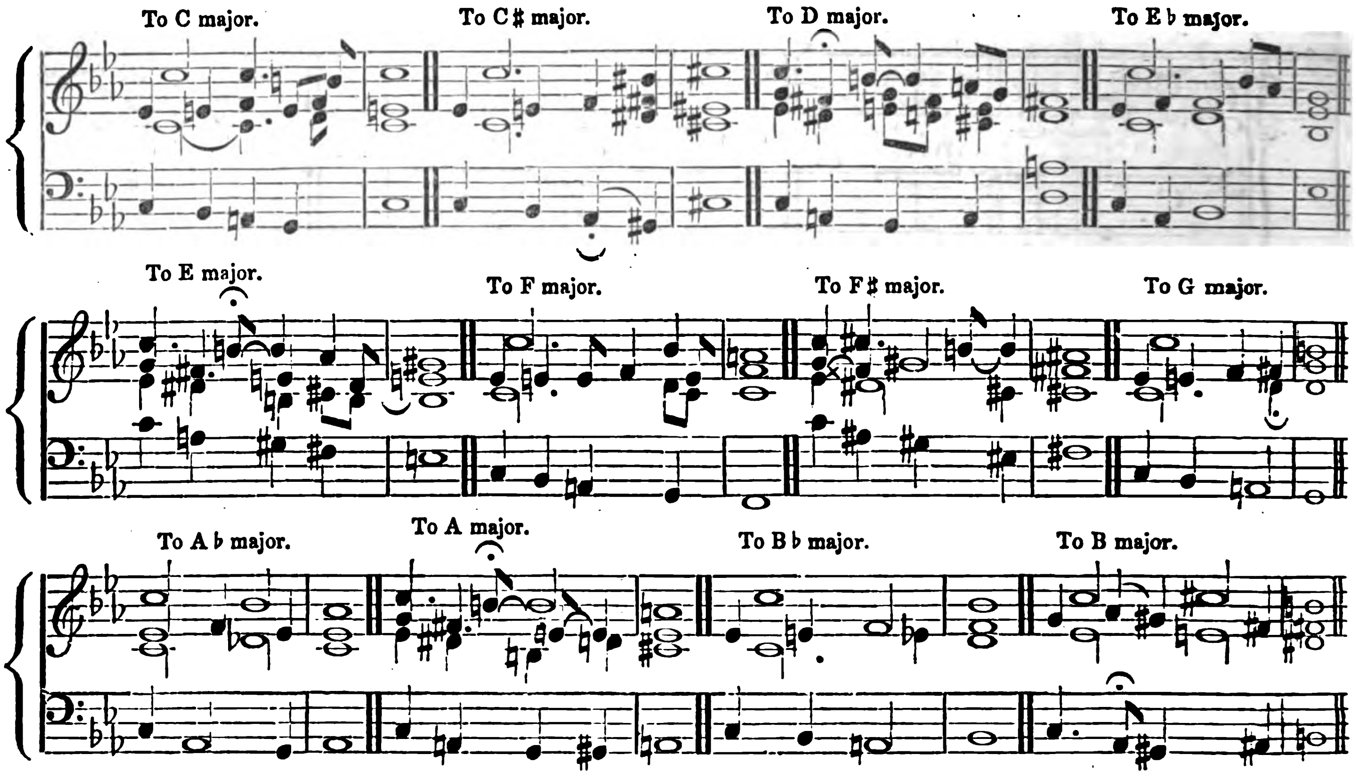


Leaving the minor key of A.

We shall close this section by presenting to our readers a Table showing the mode in which a modulation from the keys of C major and C minor may be taken to every other key in the scale, which by transposition may be made available in proceeding from any keys whatever to any other sought, and in four parts.




To A ♭ major.
To A major.
To B ♭ major.
To B major.
To C minor.
To C ♯ minor.
To D minor.
To E ♭ minor.
To E minor.
To F minor.
To F ♯ minor.
To G minor.
To A ♭ minor.
To A minor.
To B ♭ minor.
To B minor.
MINOR.
C minor to C ♯ minor.
To D minor.
To E ♭ minor.
To E minor.
To F minor.
To F ♯ minor.
To G minor.
To A ♭ minor.
To A minor.
To B ♭ minor.
To B minor.

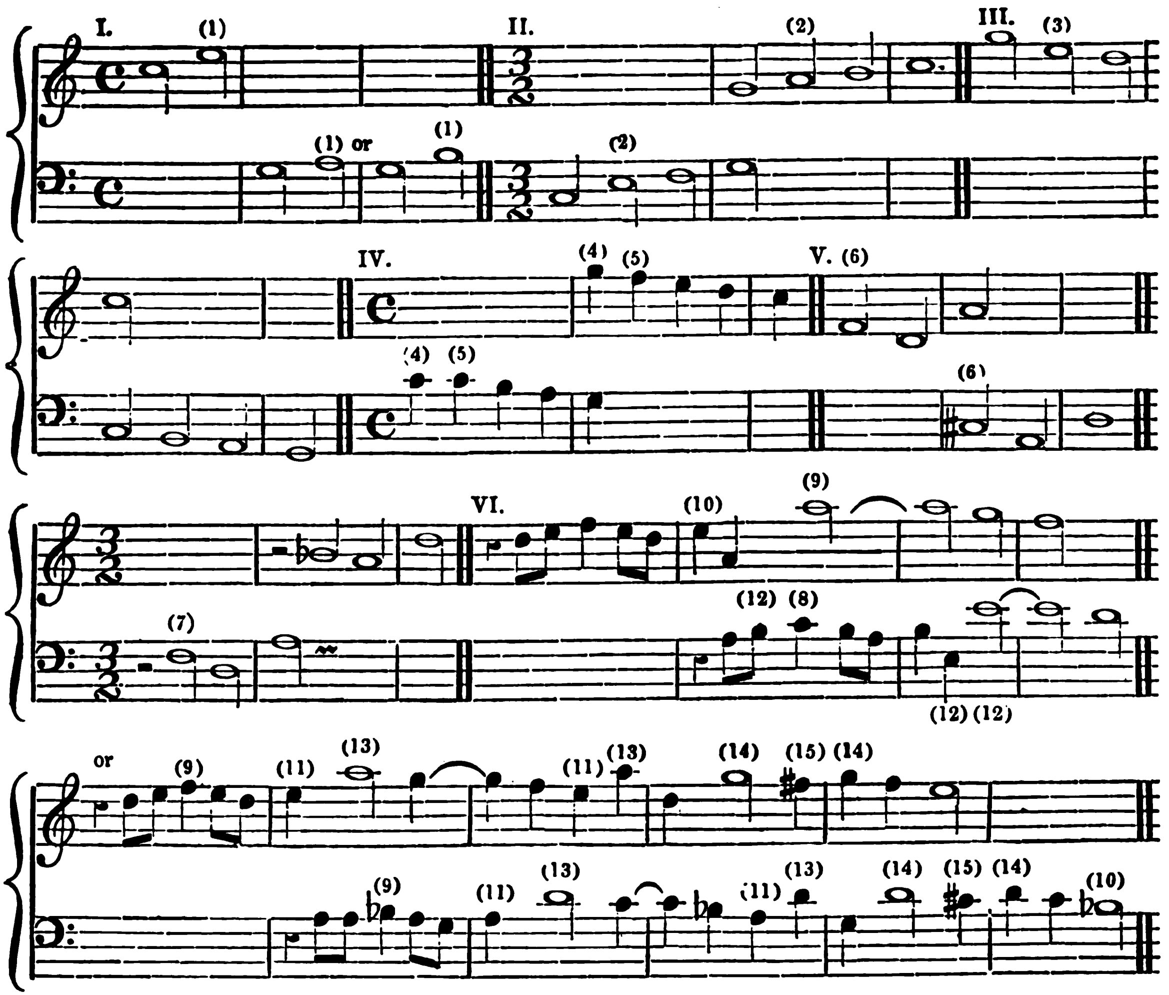


By the transposition of the above Table into all the different keys it is clear that we shall obtain its converse; those, however, who wish to save themselves that labour may consult the authority we have above used, namely, *The Art of Musical Modulation digested in twelve Tables*, by Philip Joseph Frick; who at one period of his life was organist at the Court of the Margrave of Baden, and died in England in 1798, having been also author of a *Treatise on Thorough Bass*, published in 1786, which it has not been our good fortune to have seen.

Fugues, canons, and imitations.

Fugue, as well as imitation, consists in a certain repetition of the melody in the different parts or their following each other at intervals of time, each repeating what the first had performed according to certain rules. The part which leads is called the *guide*, and that which repeats it the *answer*. The latter always proceeding by the same species of intervals, or in other words, the relative situations of the tones and semitones standing in the same order in one part as they do in the other. Of imitation, as it requires no particular skill, we shall merely observe that it consists in a certain continuance of the melody in any of the parts repeated at pleasure, and without very great regularity; and that it is only in the repetition of this melody that it resembles fugue.

In writing fugues the following are the principal rules to be attended to: First. The key note and its fifth for the first and last notes of the fugue are preferable to any other, especially if you are not thoroughly master of the mode of proceeding with them. The melody in this case is to be contained within the octave to the key. If it exceed those bounds, such as are above or below the octave are deemed the same as those within the octave. Secondly. If one part begin or end with the key note, the other begins and ends by the fifth, and so of every other note that answers within the octave to the key, and they must be so contrived that the notes between the key note and the fifth may answer equally in each part, inasmuch as the agreement and regularity necessary in the notes beginning and ending the fugue, should be equally observed through the whole continuance of the melody whereof the fugue is composed. Thirdly. Whereas in diatonic progression, either in ascending or descending from the key note to its fifth, and the contrary, there is one note difference, you may make one of those two notes in conjoint degree of that progression that contains the greater number to agree with the progression that must be unavoidably used wherein there is one note less and that in the middle of the melody. Thus, if the melody of the fugue proceed by descending from the key note to its fifth, we can therein only use the sixth and seventh notes; but in order to make the same melody equal in descending from the fifth to the key we can pass upon the fourth, third, and second notes, so that we choose one of the three last notes nearest the key note on which the air of the fugue ends, so that the melody nearly approximates that first heard. Also, taking the progression containing the greater number of notes, that which contains the least number must be made to agree with it rather towards the end than at the beginning of the melody. The following examples will better explain this.



In the first example, the sixth or seventh answers to E in the Guide. (1). In the second, the sixth answers to the third. (2). In the third example, the seventh corresponds with the third. (3). In the fourth, the fifth (4) or the fourth (5) answers to the key notes. In the fifth example, the third corresponds with the seventh (6) or to the sixth. (7). In the sixth, the third answers to the seventh (8) or to the sixth, (9), the second answers to the sixth (10) or to the fifth. (11.) The fifth answers to the second (12) or to the key, (13), and the key note answers to the fourth. (14).

Artificial discords. Fourth.

There are many other points to be noticed in the choice between the five notes ascending to the fifth of the key, to make an air answer to that of the four notes from the fifth to the key note ascending whether the air ascend or the contrary, inasmuch as there are always five notes one way and four the other; it is sometimes necessary to borrow even the second note or the fourth for the purpose of making up five notes from the fifth to the key note ascending, or which is the same, from the key note to the fifth descending; which matters will be subjoined in the eleven following observations.

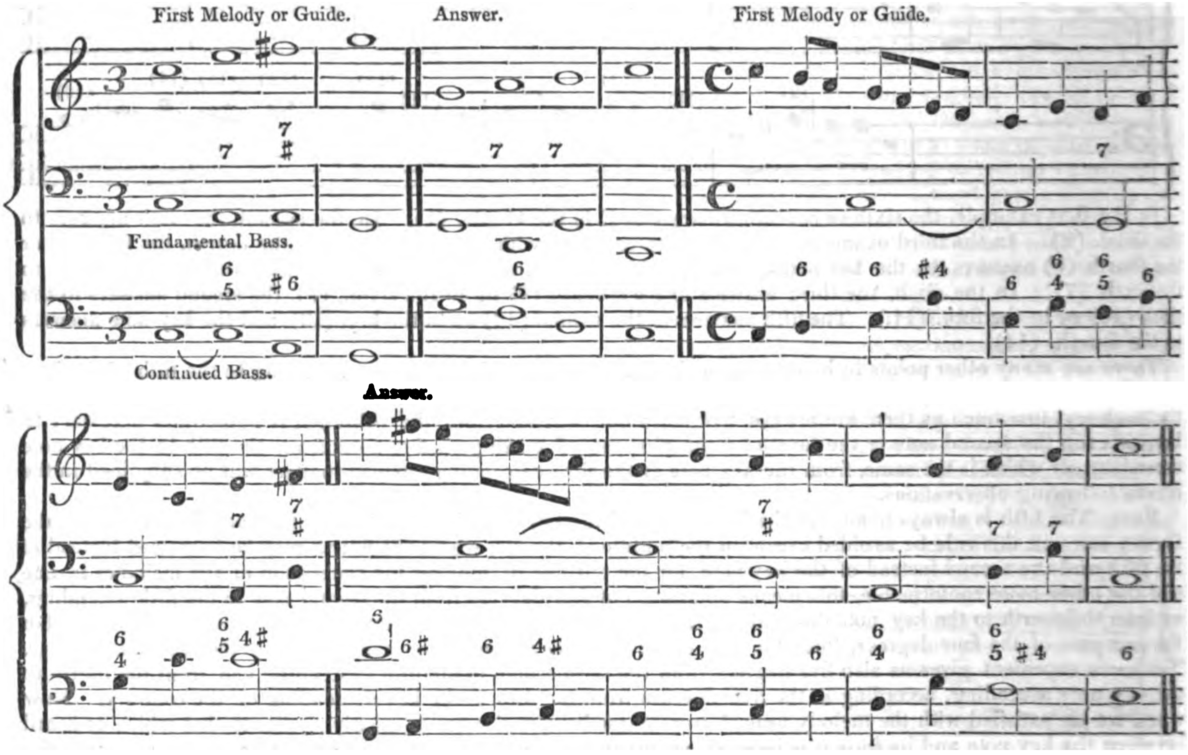
First. The fifth is always to answer the key note, and the key note the fifth in the first and last notes of the fugue; nor can this rule be avoided except in the middle of the air, where the fourth may be borrowed instead of the fifth and the second instead of the key note, for the purpose of making the succession of the melodies in one and the other more conformable, this means affording but four degrees from the second note to the fifth ascending, or from the fourth to the key note descending, from which an air may be composed nearly similar to that within the compass of the four degrees, from the fifth to the key note ascending or from the last to the other descending. The same expedient gives us also five degrees from the second note to the fifth descending and from the fourth to the key note ascending, according to the five degrees from the fifth to the key descending or the contrary. Now when we are satisfied with the melody formed from these borrowed notes as nearly similar to that which is heard between the key note and its fifth, it is because, on account of the diatonic scale, it cannot be exactly the same, the notes of which scale being unchangeable by new sharps or flats except in minor keys, wherein a flat is added to the sixth note in descending and a sharp to the leading note in ascending; with the liberty also of sometimes adding a sharp to the third of all minor keys, and to the fourth of all keys when they stand in the place of a leading note, as may be seen in the sixth example on the notes marked (15), so that the notes make a major third or a sharp sixth with the bass.

Secondly. Having found the bass of the fugue, you may then seek for the other parts that may accompany the melody or bass, in which it is to be observed that the bass and other parts nearly follow the same progression as the first melody and its answer; moreover, he bass will admit the same relative chords in one as in the other if the imitation be correct. Thus by the aid of the bass and of the other parts may be found the means of making several fugues heard together, or of composing another sort of fugue called a canon whereof mention will be hereafter made.

Thirdly. Several basses may be written to the melody of a fugue, or the melody may be written to suit a bass more than any other part; but this is of no consequence, inasmuch as by inverting the chords various basses may be composed, or a part may serve as a bass though the melody might be more suitable to an upper part. Nothing is more agreeable than alternating these different ways of accompanying a treble or bass, more especially in a fugue where variety is only discernible in the accompanying parts. And when we said that the bass of a fugue might always be nearly the same, it was to give the most perfect idea of the mode in which the melody of a fugue ought to be imitated, the similarity of the chords being of itself a sufficient proof of it.

Fourthly. To ascertain the choice to be made of notes within the compass from the key note to its fifth ascending and from that to the other descending, we must ever be mindful of the key note and its fifth which are usually the boundaries of the melody of a fugue, but we are not to be so restricted as to prevent us from making the intervals of the answer conformable to those of the fugue inverted, especially in the middle of the air. Thus, having the interval of a third, fourth, fifth, sixth, or seventh in the middle of the first melody, the like should come in the same part of the melody that answers the first and so of the others. This, however, is a rule from which deviation may take place in favour of a diatonic progression or of the principal notes of a key, keeping in view rather what follows than what precedes, and also the key note and its fifth, which generally begin and end the fugue, rather than the similarity of intervals we have laid down. Hence the interval of a fourth often answers that of a fifth, and the latter often answers the former. If, however, one or more diatonic intervals occur after a consonant interval, recourse must be had to those places where the key note appears, that the diatonic progression which is found from the last consonant interval until the key note be duly imitated in the answer until the fifth, or if the progression lead to the fifth it must be imitated in the answer towards the key note, especially if a progression of either sort and by a cadence, for the final cadence of a fugue should always be upon the key note and upon its fifth. But if the cadence do not absolutely end the fugue, the fourth may be used instead of the fifth.

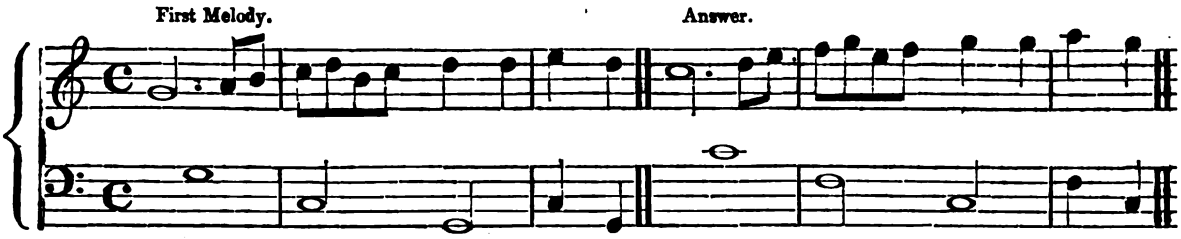
Fugues should seldom begin or end but by the key note, its fifth, or its third, the sixth or seventh then answering to that third, as may be seen in the fifth example above given. Thus by adhering to what follows rather than to that which precedes, and by the similarity of the chords that are to meet over the bass employed to melodies which answer one another in fugue, a mistake will seldom occur. We subjoin some examples.

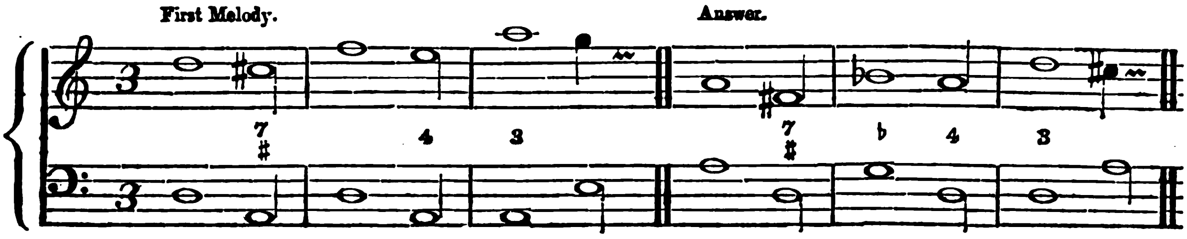


In the above example the continued bass shows that whatever bass you imagine to a melody proposed as the subject, it may always have a similarity by carrying the same chords. In this case, however, the fundamental is still better.

Fifthly. The melody or subject of a fugue should not be composed of less than half a bar; if it contain more than four bars the answer must begin in the fourth, but the movement should be somewhat quick that so much melody without harmony may be agreeable.

Sixthly. Any of the parts may begin the fugue, but it must naturally end upon the first part of the bar or measure when divided into two parts, and on the third part of the bar when divided into four parts. If it end in any other part, it is for the sake of the words or some caprice of the composer. Novelty allows an occasional trespass on these rules which are founded on good taste, and the surprise caused by their violation can only be pleasing in the hands of a master possessed of judgment and discretion. Fugues may end also upon other notes than the key note and its fifth. We here give some examples in illustration of what has been advanced.



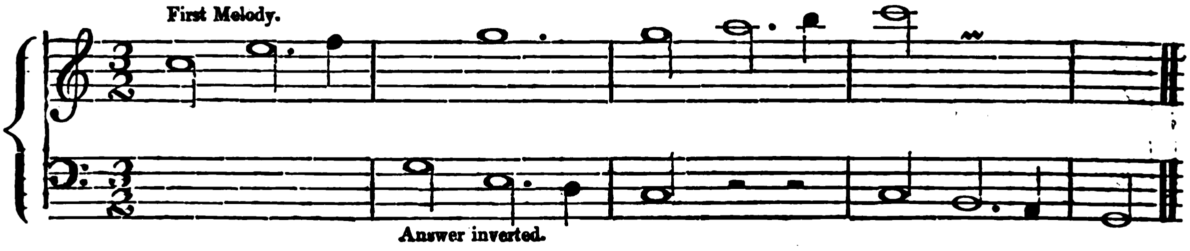


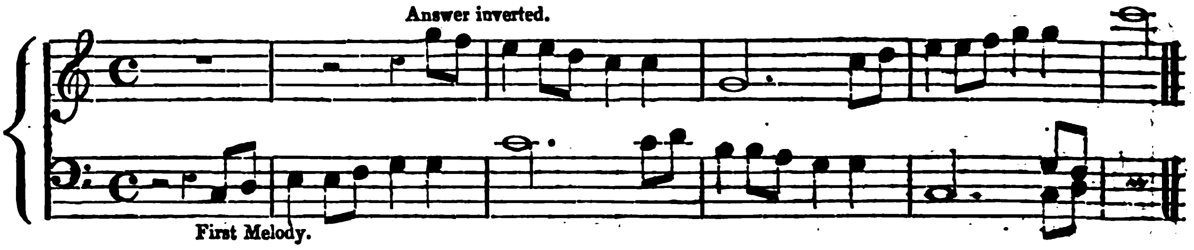
Seventhly. The melody of the fugue must be imitated as nearly as possible. The same number of semibreves, minims, &c., contained in any part of the measure must be employed wherever the fugue is heard.

Eighthly. Each part may be begun in the unison or the octave of the first part, but the effect is much more striking and agreeable when the parts follow each other at the fourth or the fifth. A fugue may commence and be answered by any of the parts throughout the composition. If the key be changed, every note of the fugue must be relatively the same in the new key as to degrees as well as to quantity and measure.

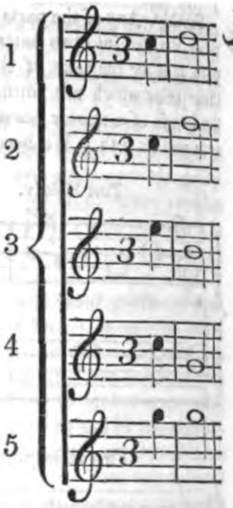
Ninthly. We may wait until the melody or subject of the fugue be entirely completed, each part answering it after the other, but as sometimes in the middle of the design each part may be contrived to answer, the effect is good if nothing be changed. See the sixth example.

Tenthly. Much grace and variety in the harmonies may be effected by *inversion*, for having designed and arranged the subject, it may be inverted in such a manner that the subject which has been heard ascending may be heard descending and the contrary without any other change, as under.



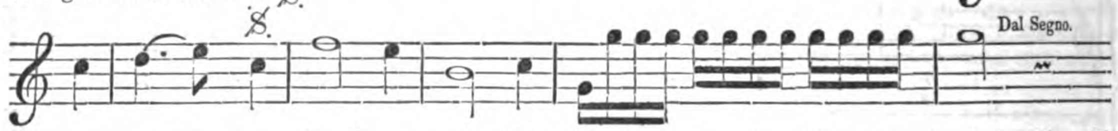


Eleventhly. Several fugues may be introduced together or after each other; they should, however, be so brought in as not to begin on the same part of the bar, nor in the same bar, especially for the first time. It is well to invert their progressions, and increase and diminish the value of the notes as to time; and if they cannot be heard together a part of one may at least be heard with part of another. To this we will add, that if the student desire to see what can be done, and that beautifully, in treating a fugue in every possible shape, and to profit by it, the fugues of John Sebastian Bach will afford him abundant opportunity.

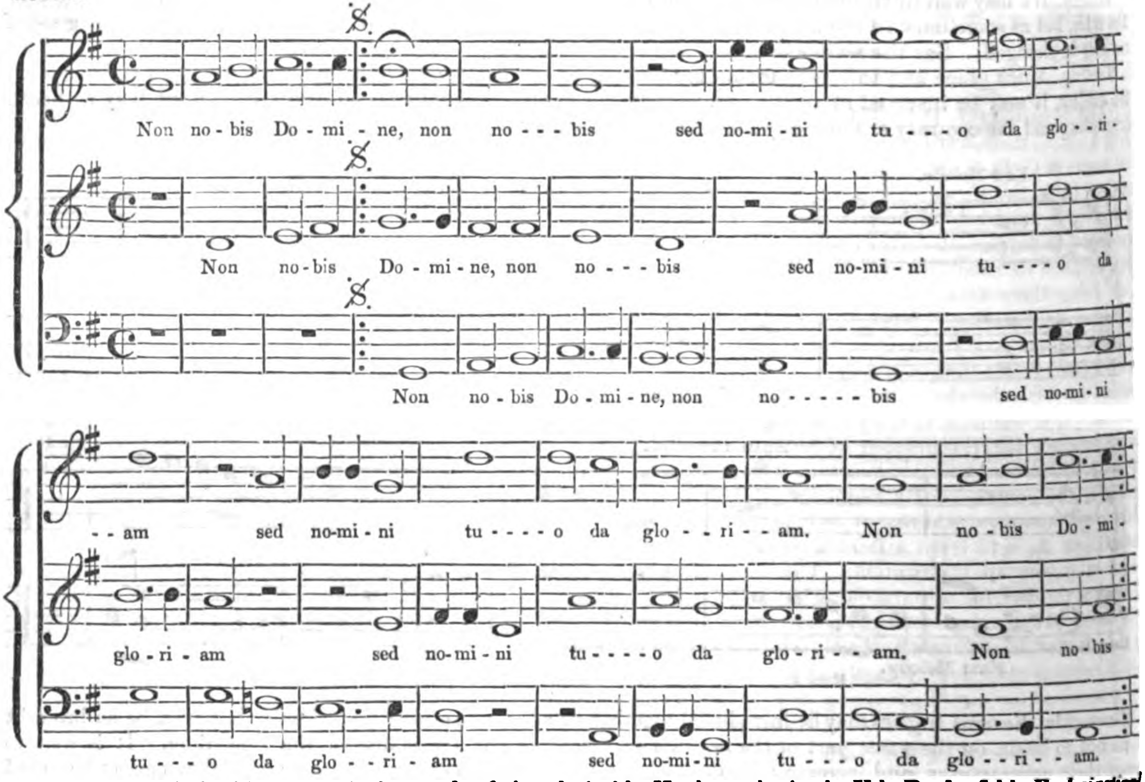


The canon is a species of fugue, sometimes called a perpetual fugue. It consists in an air the subject of which is repeated in all the parts. The most common are those taken in the unison or in the octave, and they are treated according to the extent of the voices or instruments employed. To compose this species you make your subject at pleasure, adding as many parts as you think proper; of these an air is composed with the melody so contrived that one part serves as a prolongation of the other. After this the air begins by one of those parts, and this is immediately followed by another at the time the first subject is ended. Thus each part following the other when the first is concluded, it recommences, still followed by the others as at first, care being taken that each part began at its proper place. If one of the subjects contained in each of the five parts in the margin were selected, the others might be easily added, and thence an entire air made wherein all the difficulty of this canon consists, namely, in the air.

The melody of the five parts is very obvious in the canon below, which is founded on the bar at the side hereof, some notes are added merely for the sake of the air; and it must be observed that the parts begin the air after each other when the preceding one is at the mark 𝄋.



This perpetual fugue may be taken up at the fifth and at the fourth; when this is done the whole of the melody must be arranged and accidental sharps and flats, as requisite, added to those notes where the use of the natural degrees would prevent the air from being exactly similar without regarding the modulation but the melody only, whence its difficulty; because each time that a part takes up the fugue it must enter a new key, as the fifth if the part takes up at the fifth, or the fourth if taken up at the fourth. Whereas in the canon above given the parts are unlimited in number, so in that whereof we have just been speaking they do not exceed four parts. We shall here place before the reader the finest specimen now extant of this kind of Music, which Callcott says "will ever remain a lasting ornament to the taste and science of the Country in which it was produced;" to which we will add, that we do not believe there is any composition whatever that has been so often performed since it was written.


Non no - bis Do - mi - ne, non no - - - bis sed no-mi - ni tu - - - o da glo - - ri -
Non no-bis Do - mi - ne, non no - - - bis sed no-mi - ni tu - - - - o da
Non no - bis Do - mi - ne, non no - - - - - bis sed no-mi - ni
- - am sed no-mi - ni tu - - - - o da glo - - ri - - am. Non no - bis Do - mi -
glo - ri - am sed no-mi - ni tu - - - - o da glo - ri - - am. Non no - bis
tu - - - o da glo - - ri - am sed no-mi-ni tu - - - o da glo - - ri - - am.

We shall conclude this part with the words of the admirable Hooker, who in the Vth Book of his *Ecclesiastical*

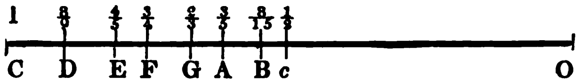
Polity says, "Touching Musicall harmony, whether by instrument or by voyce, it being but of high and low in sounds a due proportionable disposition, such notwithstanding is the force thereof, and so pleasing effects it hath in that very part of Man which is most divine, that some have beene thereby induced to thinke that the soule itself by Nature is, or hath in it harmony. A thing which delighteth all ages and beseemeth all states; a thing as seasonable in griefe as in joy; as decent being added unto actions of greatest waight] and solemnitie, as being used when men most sequester themselves from action. The reason hereof is an admirable facilitie which Musicke hath to expresse and represent to the mind, more inwardly than any other sensible meane, the very standing, rising, and falling, the very steps and inflections every way, the turnes and varieties of all passions whereunto the minde is subject: yea so to imitate them, that whether it resemble unto us the same state wherein our mindes alreadie are, or a cleane contrary, wee are not more contentedly by the one confirmed than changed and led away by the other. In harmony the very image and character euen of Vertue and Vice is perceived, the mind delighted with their resemblances, and brought, by having them often iterated, into a loue of the things themselves. For which cause there is nothing more contagious and pestilent then some kindes of harmonie; then some nothing more strong and potent unto good. And that there is such a difference of one kinde from another, we neede no proof but our owne experience, inasmuch as wee are at the hearing of some more inclined unto sorrow and heavinesse; of some more mollified and softened in minde; one kinde apter to stay and settle us, another to move and stirre our affections; there is that draweth to a marvellous grave and sober mediocritie; there is also that carryeth as it were into extasies, filling the minde with an heavenly joy and for the time in a manner severing it from the body. So that although we lay altogether aside the consideration of dittie or matter, the very harmony of sounds being framed in due sort and carryed from the eare to the spirituall faculties of our soules, is by a natiue puissance and efficacie greatly available to bring to a perfect temper whatsoever is there troubled, apt as well to quicken the spirits as to allay that which is too eager; soveraigne against melancholy and despaire, forcible to draw forth teares of devotion, if the minde be such as can yeeld them, able both to moove and to moderate all affections."

On Musical Temperament and the Compass of Voices and Instruments in an Orchestra.

Temperament.

As in our imperfect instruments and common notation of Music only twelve intervals of sound are admitted into the octave, and as intervals or concords, though of the same name as thirds, fourths, &c., do not consist of the same degrees or elements, though there may be always the same number of them, as some fourths or fifths are perfect and others not, a deviation from truth and nature is necessary to accommodate or mend the imperfect concords by transferring to them part of the beauty of the perfect in order to remedy the defect. The process by which they are accommodated or tempered is called temperament.

If a string be stretched between two bridges and it be stopt in the middle, and the sound of half of it be compared to that of the whole, we acquire the idea of the interval of two sounds whose times of vibration are in the ratio of 1 to 2, and their vibrations are in proportion to their lengths, so by other divisions of the string we acquire ideas of other different intervals. Now if the Musical string



C O and its parts D O, E O, F O, G O, A O, B O, and CO, be in proportion to each other as the numbers 1, $\frac{8}{9}$, $\frac{4}{5}$, $\frac{3}{4}$, $\frac{2}{3}$, $\frac{3}{5}$, $\frac{8}{15}$, $\frac{1}{2}$, their several vibrations will exhibit the system of the eight sounds to which Musicians have given the names of C, D, E, F, G, A, B, *c*. If we tune accurately four following fifths upon an instrument or string, as C, G, D, A, and E, we shall find that the last fifth E will be a discordant major third with the C from which we started, and, indeed, too sharp for the ear to bear; in short, it is not the same E produced as a fifth from A which we ought to have as the third of C. Let us suppose a string long enough to sound the interval from C to E as above, and its subdivisions into fifths be taken as relates to the length of the string, they will stand as follows, each being three times the length of the preceding, C = 1, G = 3, D = 9, A = 27, E = 81, which will represent its quantity. Now the third major E from C in the above diagram is $\frac{4}{5}$ of the string C O, or which is the same, $\frac{1}{5}$ from C, or the octave itself will be represented by 5; then we shall have them going by octaves each double the preceding, thus E = 5, E = 10, E = 20, E = 40, E = 80. But by the first operation we had E = 81, therefore these two E's are different and their ratio is $\frac{80}{81}$, which is exactly the value of a major comma. It is manifest that by following up this system of ratios we may obtain those of any intervals sought. If we produce the progression of fifths to the 12th power, which will happen on B sharp, we shall find that this B sharp will exceed the C wherewith it should be in unison, and that it is in the ratio to it of 531441 : 524288, which is the comma of Pythagoras. By the preceding calculation the B sharp should have exceeded the C by three major commas, whereas it only exceeds it by the comma of Pythagoras. The same sound then E, which is the fifth of A, is to form a third major of C; it is the division of the overplus in the octave which is to be tempered in tuning an instrument. This is not the place for a further investigation of the subject which properly belongs to the doctrine of harmonics, but we thought the simple and concise view we have taken of it would be acceptable to the Musician who would not be inclined to study that doctrine. The following is a Table from Dr. Smith of the ratios of the different intervals which we think useful to him.

Perfect Ratios.	Intervals' Names.		Mark.	Elements.
C : *c* :: 2 : 1	C *c*	Octave.	VIII.	3 T + 2 *t* + 2 H.
B : *c* :: 16 : 15	B *c*	Hemitone.	H or 2nd.	
C : B :: 15 : 8	C B	VII. major.	VII.	3 T + 2 *t* + 2 H.
C : D :: 9 : 8	C D	Tone major.	T or II.	

Perfect Ratios.		Intervals' Names.		Mark.	Elements.
D : *c* ::	16 : 9	D *c*	7th minor.	7th.	2 T + 2 *t* + 2 H.
A : *c* ::	6 : 5	A *c*	3d minor.	3rd.	T + H.
C : A ::	5 : 3	C A	VI. major.	VI.	2 T + 2 *t* + H.
C : E ::	5 : 4	C E	III. major.	III.	T + *t*.
E : *c* ::	8 : 5	E *c*	6th minor.	6th.	2 T + *t* + 2 H.
G : *c* ::	4 : 3	G *c*	4th minor.	4th.	T + *t* + H.
C : G ::	3 : 2	C G	V. major.	V.	2 T + *t* + H.
F : B ::	45 : 32	F B	IV. major.	IV.	2 T + *t*.
B : *f* ::	64 : 45	B *f*	5th minor.	5th.	T + *t* + 2 H.
D : E ::	10 : 9	D E	Tone minor.	*t*.	
	81 : 80		Comma.	*c*.	T — *t*.

Tuning the organ. The mode of tuning the organ as recommended by Mr. Flight, a very skilful maker of the instrument, is to divide the comma, or rather to distribute it over the instrument, instead of taking a series of perfect fifths, to make each sufficiently flat to meet the error in the pitch of E, thus in the four fifths each would lose a quarter of a comma and the major third will be perfect. From this E a similar set of fifths tunes B, E sharp, C sharp, and G sharp, which last will then be a perfect third to E. Then going back to C, we must tune the F below, a quarter of a comma too sharp to make C flat as a fifth in respect of F, and proceeding then to tune B flat and E flat in a similar manner, the scale will be tuned by the common temperament. This method leaves the major thirds and minor sixths perfect in scales not having more than three sharps or two flats in the signatures. Beyond that the major thirds and minor sixths are harsh. So the minor thirds within those limits are too flat and the major sixths too sharp by a quarter of a comma, and the fourths equally too sharp. G sharp when standing for A flat excepted. Those intervals which are changed, by diesis, an interval less than a comma, have received the name of *wolf intervals*, from the howling sort of noise produced by their beats, and that between G sharp and E flat is called the *great wolf*.

Piano-forte. The piano-forte is generally tuned by dividing the scale as nearly as may be into twelve equal semitones. To accomplish which the fifths are kept sharper than in the above temperament, being flattened not more than the eleventh part of a comma. Thus the wolves disappear, but the thirds, and major and minor sixths are too harsh for the organ.

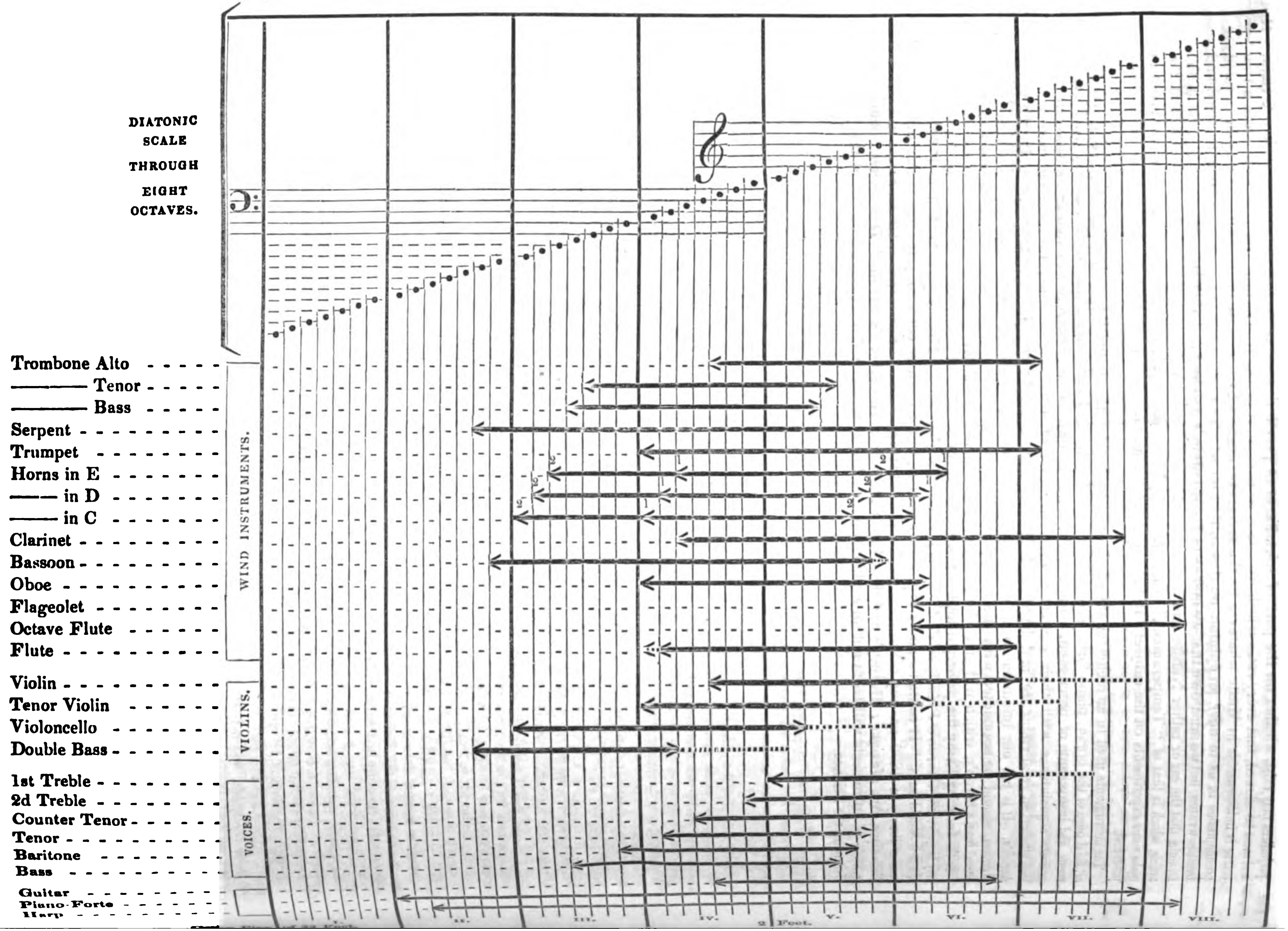
De Momigny. Notwithstanding the general reception of temperament as we have above explained it, there are those who do not admit its rules, and when we find so learned and celebrated a Writer as De Momigny among them, we confess ourselves somewhat puzzled. We shall give his view of it. He says, because by four consecutive fifths or twelfths C 1, G 3, D 9, A 27, E 81, a different E is obtained from that formed by the octaves of the fifth and the C itself, namely, E $\frac{1}{5}$, E $\frac{1}{10}$, E $\frac{1}{20}$, E $\frac{1}{40}$, E $\frac{1}{80}$, persons have reasonably concluded that a temperament was necessary to bring these two E's to the same pitch if we wish them to agree. To make them agree do we make them meet half way? No! It has been decided that the E 81 being the only wrong party concerned in the affair should be at the whole expense of making good the damage, by submitting to the E 80, which is not to be moved. Where then is the temperament? It is in the diminution of each of the four fifths $\frac{C\ G}{1\ 3}$, $\frac{G\ D}{3\ 9}$, $\frac{D\ A}{9\ 27}$, and $\frac{E\ A}{27\ 81}$, for this E 81 being not only too high in the fifth last taken E, but equally so in the other three fifths, all four are to be flattened not to reach 81 but 80 only. If the mathematical point be 81, why not let the fifths reach it? We have just said why it is that 81 may become 80. Have nature and the mathematics two weights or two measures here, inasmuch as by one we reach 80 and by the other 81? If these points are both equally natural and mathematical why sacrifice one to the other, and why is the justness of the triplicate progression sacrificed to the other. Do they say that the ear, inexorable on the justness of the octave, is indifferent with regard to fifths? because that would be saying that the ear was a perfect judge of an octave, but a partial one in respect of a fifth. How do we find in the ear this scrupulosity which murmurs at the least defect in the octave and relaxes with regard to the fifth? Has the ear also two weights and two measures, or is it not clear in respect to the octave? It appears to me, says De Momigny, that if it is a good judge of one interval it is not less so of another, and consequently that the fifth which they call tempered, not to call it false, is at least a just musical fifth if it be not a just mathematical fifth, because it seems to me absurd that Nature should contradict herself in her most simple operations. One of these two things must be true. Either that the data of the triplicate or subtriplicate ratios are not Musical, or that they ought to agree with those of the duplicate or subduplicate proportion, if Nature ever intended that they should unite, without which it is evident she contradicts herself. But the triplicate ratio giving 81 and the duplicate ratio 80, if these terms are both of them natural and mathematical and ought to reunite and become identified with one another so as to be a true octave, it follows that the mathematical fifth should be too sharp or out of its true Musical proportion, and at the same time that one of these ratios cannot be exact, and can only serve as an approximation and not as a perfect guide. Then to tell Musicians that they tune, sing, and play false, when they only correct the anti-Musical data of the mathematics, is unjust and unreasonable towards them, inasmuch as they cannot be wrong in substituting what is correct for that which is incorrect. If the ear had not been constantly opposed to the sophists, who maintain that the data of the monochord are true as well as canonical and Musical, their false scale would long since have been substituted for ours. Is it not strange that they should allege our scale to be false because it does not agree with the data of the monochord, when, on the confession of the patrons themselves of the monochord, of all the intervals which derive their proportions from the regulating string, it is the octave only which is false in the result? The smallest or elementary interval being the semitone and the greatest the octave which recommences the system, it is only necessary to form the semitones and octaves Musically true to have the keys in tune and proper for playing equally well in every key. He finishes by observing, whatever prejudices may exist, whether on the part of scientific or of practical men respecting temperament, it is certain, and must be allowed, that every ratio which oversteps or falls short of the true octave is a false ratio, since a true octave is indispensable in Music whatever be the species of degrees by which we arrive at it. It may be deemed presumptuous in us to offer an opinion on this subject on which so many learned men have been engaged and treatises written, but we must own that we incline to De Momigny's opinion, and that it is from some defect in the formulæ that the ear or rather Nature and mathematical science are at variance. De Momigny at the end of the article, which is that of "Temperament," in the *Encyclopédie Méthodique*, 1818, mentions that he was about to make some experiments on the subject; if he has done so, we are not aware that the results have ever been published.

Instruments and their compass.

The instruments used in an orchestra are of three sorts besides the natural instrument of the voice and the artificial ones of the organ, piano-forte, and guitar; namely, stringed instruments played with a bow, wind instruments, and instruments of percussion. Each of these has its own peculiar character as well as compass; it is by intimate acquaintance with their character, especially that of wind instruments, that the German masters have attained so great eminence, and have produced surprising effects by combining instruments unknown to the Ancients. It is not our intention to detail these instruments separately, but as the reader, and especially the Musician, should be acquainted with the compass of them, we have on the following page subjoined a synopsis, altered from Choron's, which will give him at once the information requisite.

In the foregoing Essay the principal authorities we have consulted, and upon some of which we have drawn very largely, are Choron's *Principes de Musique*; Pepusch's *Treatise on Harmony*, published in 1731, a Work of which Shield says, "It contains many exploded doctrines, but it likewise contains principles which will be the basis of theory in 1800 or any other Century." Rameau; Dr. Callcott's *Musical Grammar*; *Encyclopédie Méthodique*, Art. *Musique*; Burney's and Hawkins's *Histories*; Grassineau's *Musical Dictionary*. After the synopsis of instruments will be found an explanation of technical terms used in Music, and a list of the principal Writers on the Science.

SYNOPSIS *of the* COMPASS *and* SCALES *of the different* INSTRUMENTS *of an* ORCHESTRA *and of the* HUMAN VOICE.



EXPLANATION

OF THE

CHIEF TECHNICAL TERMS USED IN MUSIC.

Abbreviations are strokes over or under a semibreve, minim, or crotchet, which divide them into quavers if there be only one stroke; if two strokes into semiquavers; if a triple stroke into demisemiquavers.

Accent. The stress or expression given to certain parts of a bar or measure.

Acciaccatura. A grace note one semitone below that note to which it is prefixed.

Accidentals. Those flats and sharps which occur in a movement, besides those which are prefixed in the signature.

Accord. See *Concord.*

Accrescimento. The increase of the length of a note one half of the duration it originally has by means of a dot appended to its right side.

Acute is understood of a sound or tone which is high in respect of another.

Adagio, written Adag°. and Ad°., an Italian word denoting the slowest of the Musical time, grave excepted.

Added lines and notes. Those lines and notes above and below the staff, which, proceeding higher or lower than the staff itself, cannot be contained within it.

Ad libitum. A term used to denote that the time of the portion of the movement to which it is prefixed is to be at the performer's pleasure.

Affetto, or *Affettuoso*, prefixed to a movement, shows that it is to be performed in a smooth, tender, and affecting manner, and thence rather slow than fast.

After note. A small grace note which, in contradistinction to the appoggiatura, follows a larger one, and depends upon that for its time.

Alla breve. The name of a movement whose bars consist of two semibreves or four minims; it is denoted by a barred C or semicircle.

Allegretto. A diminutive of allegro: it is a time rather quick, but not quite so quick as the allegro.

Allegro. A term used to signify that the movement is to be performed in a brisk, lively manner, but without hurry or precipitation, and quicker than any other time, except that marked presto. The usual six distinctions of time succeed each other in the following order: grave, adagio, largo, vivace, allegro, and presto. If allegro be preceded by the word piu it adds to the strength of the signification, intimating that the time must be brisker and gayer than allegro. If preceded by poco, it weakens the signification, and intimates that the time must not be considered quite so brisk and lively as allegro.

Al segno. A notice to the performer that he is to return and commence the repeat at the sign 𝄋.

Alto. The countertenor part.

Andante signifies, especially in thorough bass, that the notes are to be played distinctly.

Apotome. The remaining part of an entire tone after a major semitone has been taken out of it.

Appoggiatura. A small note placed before a larger one of longer duration from which it usually borrows half its value. It always occurs on the strong or accented part of the measure. Sometimes it is only one quarter of the length of the note it precedes.

Arioso, or *Legato.* See *Legato.*

Arpeggio, or *Arpeggiato.* The imitation of the harp on any instrument susceptible of such imitation by striking the notes of a chord in quick and repeated succession.

Arsis and Thesis. . Terms used in composition, as when a point is inverted or turned, it is said to move per arsin et thesin; that is, when a point rises in one part and falls in another where an agreeable variety is produced. Also the rise (arsis) and fall (thesis) of the hand in beating time.

Assai. An Italian adverb of quantity often joined to the words allegro, adagio, presto, &c., and signifies that the measure and motion of the piece should be kept in a mean degree of quickness or slowness, quick or slow enough, but not too much of either.

A tempo giusto is a direction to play in the true just time. See *Battuta.*

Atto di cadenza is that disposition of the notes which not only makes a cadence in one part, but directs and points it out in others. Thus when the bass rises a fourth, or falls a fifth, this motion is really a cadence, and at the same time it is a sign that the other parts thereupon perform their proper cadences.

Authentic melodies are such as have their principal notes contained between the key note and its octave.

Back fall. The name, now never used, of one of the old English graces.

Bar. A stroke vertically drawn across the stave, including between each two a certain quantity or measure of time, varying as the Music is either triple or common.

Baritone. Called by the French basse taille. It is, in fact, a high bass, and in the ancient Church Music is written with the F clef upon the third line.

Bass. The lowest or deepest of the parts in Musical composition.

Baton. Used to denote a rest of four semibreves.

Battuta. The motion of beating time with the hand or foot. By the Italians the phrase *A tempo giusto* is used after a recitative to show that the measure is to be beat true and just, which during the recitative was conducted irregularly to suit the action, or express some passion, &c. &c.

Beat. A reversed shake without a turn.

B molle. One of the notes in the scale of Music, usually known as B ♭, or soft in opposition to B quadro.

B quadro, or *quarré.* Taking its name from its figure ♮. This is generally called B natural or sharp, in contradistinction to B mol or flat. As the ♭ placed before any note signifies that it is to be lowered a semitone minor, so does the quarré or ♮ raise it to its diatonic situation.

Bind. The same as ligature or tie, to group notes together.

Bis. Where this word is placed over passages which have dots placed after one bar and before a subsequent bar, it signifies that the passage is to be twice played.

Brace is the line or bracket at the beginning of each set of staves in every line that ties them together in a vertical direction.

Breve. A note formed like a square without a tail, and equal to two semibreves or four minims. It signifies also a measure of quantity which contains in beating two down strokes with the hand and two strokes up, but this only in common time with the mark C. See *Alla breve.*

Brillante. Brisk, airy, gay, and lively.

Cadence is the termination or fall of the notes on a chord or note closing the strain and naturally expected by the ear, and is much the same in Music as the period which closes the sentence in a discourse. It is perfect when the harmony of the fifth precedes that of the key note, and imperfect when the key note with its harmony precedes that of the fifth or dominant without its added seventh, taking its name of imperfect, because the ear does not seem to acquiesce in the conclusion, but to expect a continuation of the song or whatever the Music may be. A broken or interrupted cadence, is when the bass, instead of falling a fifth, as expected by the ear, rises a second either major or minor.

Cadenza. Such an extemporary passage as the performer introduces previous to the final shake on the last note but one of a melody where a pause 𝄐 is marked.

Canon. A perpetual fugue written upon one line originally, with marks to show when the parts that imitate are to begin and end. This, however, is more properly what the Italians call the *Canone chiuso* or *Canone in corpo.* The *Canone partito* or *risoluto* is when all the parts of a perpetual fugue are written in partition, or in separate parts, with the proper pauses each is to keep or observe.

Canto, or *Soprano.* The treble part.

Canto fermo. The plain song. The Italians call every part whether plain or figured, of the subject of counterpoint, by this name.

Capriccio. A term applied to certain pieces in which the composer gives a loose to his fancy without confinement to particular measures or keys.

Characters. Those forms in Musical writing or printing which are the signs of clefs, notes, rests, &c. &c.

Chords. A combination of two or more sounds heard contemporaneously, and forming a harmony between them.

Chromatic. The introduction of semitones between each of the tones in the diatonic scale.

Clef. A mark placed at the beginning of a staff representing a note or letter of it which determines the names of the degrees. It is always placed on a line, never in a space.

Coda. The concluding passage of a movement when it occurs after a protracted perfect cadence. Its length varies, in some cases it runs to a great extent, in others it contains merely a single phrase.

Codetta. A short phrase or passage not constituting a part of a regular section, but serving to connect one section with another.

Comma. A measure of a tone, or the smallest part into which it is commonly subdivided; thus the tone between the fourth and fifth of the scale is supposed to be divided into nine small parts termed commas.

Common time, or *Equal time.* That which contains one semibreve, two minims, four crotchets, eight quavers, or their value in every measure or bar.

Composition. The art of disposing Musical sounds into airs, songs, &c.

Concertante. Those parts of a piece of Music which sing or play throughout the whole piece, either alone or accompanied, to distinguish them from those parts that only join at particular parts.

Concord. The relation of two sounds that are agreeable to the ear, whether applied in succession or consonance.

Conjoint degrees are those which adjoin each other in the order of the scale.

Consonance. The union or agreement of two sounds produced at the same time, the one grave and the other acute. Notes in consonance constitute harmony, as notes in succession melody.

Con sordini. Written short C S, with the dampers on a pianoforte, or the mutes on a violin. *Senza sordini*, or S S, signifies without them.

Continued bass. The same as thorough bass, so called because it goes quite through the composition.

Contralto. The countertenor part, or that immediately under the treble in the scale.

Contra-tenor, or *Counter-tenor.* See *Contralto.*

Counterpoint. So called originally, because the notes were points placed one against or over the other without any stems. Now every composition of many parts receives the name of counterpoint.

Crescendo. Increasing the sound from soft to loud, marked <

Crotchet. One of the notes of time equal to half a minim.

Da Capo, or *D C*, signifies from the head: it is placed to such airs as end with the first strain, and intimates that the song is to be begun again, and ended with the first part.

Dash. A small stroke thus ' placed over notes which are to be performed in a short and distinct manner.

Deceptive cadence. That which, by varying the final chord, avoids the final close.

Defective fifth, or *Semidiapente.* An interval or semitone less than the perfect fifth; it is also called the flat, lesser, or diminished fifth.

Degrees are the little intervals whereof the concords or harmonical intervals are composed. The three degrees in common use are the greater tone, the less tone, and the semitone.

Demi-ditone. A minor third.

Demiquaver. A note, two of which are equal to a quaver.

Descant. A composition in several parts. It is threefold, plain, figurative, and double.

Diapason. A musical interval by which most authors who have written on the theory of Music use to express the octave of the Greeks, as they use the terms diapente, diatessaron, and hexachord, to express the fifth, fourth, and sixth.

Diapente. An ancient term, but in modern Music signifying a fifth.

Diastem. A name given by the Ancients to a simple interval to distinguish it from a compound one, to which they gave the name of *system.*

Diatessaron. An ancient term, but in modern Music signifying a fourth.

Diatonic. That natural scale of Music which, proceeding by degrees, includes both tones and semitones. It includes all the different intervals formed by the natural notes, and also all those produced in transposing the natural scale higher or lower by employing sharps and flats.

Diazeuctic tone. In the ancient Greek Music that which disjoined two fourths, one on each side of it, and which being joined to either made a fifth.

Diesis. A division of a tone less than a comma.

Diminished interval. A defective interval, or one short of its just quantity by a lesser semitone.

Diminuendo. Diminishing the sound from loud to soft, marked thus >

Diminution. The change of the notes of a phrase or section from crotchets into quavers, quavers into semiquavers, &c. &c.

Direct. A sign ⁓ thus employed at the end of a staff to indicate upon what degree the first note of the following staff is placed.

Discord. The relation of two sounds which are always and of themselves disagreeable, whether in succession or consonance. Every discord must be prepared, struck, and resolved.

Disdiapason. A double octave.

Dissonance. The same as *Discord*, which see.

Ditone. An interval comprehending two tones.

Division. The dividing a larger interval into a number of less intervals.

Dolce. Placed at the head of movements to signify that they are to be played softly, sweetly, and agreeably.

Dominant. The sound which makes a perfect fifth to the final in authentic modes, and a third to the final or sixth to the lowest chord of a plagal mode. In modern Music, it is the fifth above the key note, and derives its name, as in ancient Music, from its requiring the key note to be heard after it.

Driving notes. See *Syncopation.*

Enharmonic scale. One divided to quarter tones. See Genus.

Extreme. A term applied to those intervals where the diatonic distances are increased or diminished by a chromatic semitone.

False cadence. One in which the bass rises a tone or semitone instead of falling a fifth or rising a fourth.

Figurative counterpoint. That wherein there is a mixture of discords along with the concords.

Flat. A sign ♭ used to depress a note one semitone.

Flat fifth. See *Semidiapente.*

Forte. Placed over a movement to signify that it is to be played loud.

Fortissimo. To signify that it is to be performed very loud.

Fourth. An interval containing four sounds or terms between its extremes, and three intervals, or as being the fourth in order of the natural or diatonic scale from the fundamental.

Fugue. A musical composition, in which the different parts commence under certain laws after each other, each repeating what the first had performed.

Fundamental bass. The lowest note or root of a chord, which is found by inverting the notes whereof it is composed, so as to bring them in thirds above such roots.

Gamut. The general scale of the notes used in Music.

Genus. A scale of Music that proceeds by certain intervals; thus that which proceeds chiefly by tones is called the Diatonic genus. If artificial sounds are inserted between the natural sounds, a scale is formed of semitones alone, which is called the Chromatic genus. When a scale is formed yet smaller in its intervals, which in some parts contains quarter-tones, it is called the Enharmonic genus.

Graces. Ornamental notes prefixed or postfixed to notes, such as the appoggiatura, the shake, &c.

Gradation. A diatonic succession of chords either in ascending or descending.

Grave. A very slow motion, slower than largo, but faster than adagio. It is also applied in speaking of sounds to denote one that is low or deep in pitch.

Grazioso. Placed over a movement to signify that it is to be performed agreeably, elegantly, gracefully.

Groups. Notes linked together at the stems.

Guide. The leading voice or instrument in a canon or fugue.

Harmonic triad. The union or chord of any note with its third and perfect fifth: it is another name for the common chord.

Harmony. The combination, or the agreeable result or union of two or more sounds heard contemporaneously.

Harpeggio. See *Arpeggio.*

Haupt-ton. The principal or written note of the shake over which the character 𝆖 is placed; the secondary or superior note is called the Hülfston. It is a German word.

Hemitone. The same as semitone.

Hexachord. A progression of six notes, to which Guido gave the names *ut, re, mi, fa, sol, la.* The hexachord is of two sorts, greater and less. The former is composed of two greater tones, and two less and one greater semitone, which make five intervals. The latter is composed of two greater tones one lesser and two greater semitones.

Hold. The same as a pause.

Homophonous. Two or more chords, strings, or voices, are said to be homophonous when they are exactly of the same pitch or in unison.

Hülfston. See *Haupt-ton.*

Hyperoche. An interval equal to nearly one comma and a half.

Imbroglio (*Tempo d'*) Music written in one measure, but really performed in another.

Imitation. A species of composition in which one part is made to imitate the other. It differs from a fugue, in that it is not restricted in the intervals at which it takes up the point.

Imperfect cadence. See *Cadence.*

Imperfect concords. Thirds and sixths are the imperfect concords, and are so called from their liability to change from major to minor, or the contrary, still however remaining consonant.

Index. The same as *Direct,* which see.

Inharmonical relation. An unexpected introduction of a dissonant sound.

Interrupted cadence. See *Cadence.*

Interval. The difference between two sounds in respect of acute and grave, or the imaginary space terminated by two sounds differing in acuteness and gravity. What we call an interval the Ancients called a diastem.

Inversion. The placing the lower note of any interval an octave higher, or the higher note an octave lower.

Irregular cadence. The same as imperfect cadence. See *Cadence.*

Key, or *Key-note.* A certain fundamental note or tone, to which the whole piece is accommodated or set, and with which it usually begins and ends.

Key-board. The platform of levers in keyed instruments, which are pressed down by the fingers to produce a percussion of the string. It is divided into long white keys and short black ones.

Lagrimoso, marked over a movement, signifies that it is to be performed in a wailing, plaintive manner.

Languente, placed to a movement, denotes that it is to be performed in a languishing and soft manner.

Large. A character denoting the greatest measure of Musical quantity, being equal to eight semibreves.

Larghetto signifies that the piece is to be performed slow, but not quite so slow as largo.

Largo. A slow motion in a movement: one degree quicker than grave, and two degrees quicker than adagio.

Leading note. The sharp seventh.

Ledger lines. The lines added above and below the staff of five lines when the ascending or descending notes run above or below it.

Legato. Notes tied together by ⌒ ⌣ these marks either over or under them, so that they are thereby properly but one note. This is also called *Syncope.*

Leggiadro. The same as allegro.

Lente, or *Lento.* Denotes that the movement is to be very slow: between grave and largo.

Limma. A small interval, rather larger than a semitone minor.

Long. A character of Music containing four semibreves.

Maestoso. Prefixed to a movement, signifies that it is to be played with grandeur, and consequently slow, but yet with strength and firmness.

Major and *Minor.* Names given to imperfect concords, which differ from each other by a semitone minor. They are also used in the same sense in speaking of discords.

Measure. A bar of Music; but more properly used to express the interval or space of time, which the person who regulates the time employs between raising and letting fall his hand, to conduct the movement sometimes quicker and sometimes slower, according to the subject to be sung or played.

Mediant. The greater third in the major scale and the lesser third in the minor scale.

Middle cadence. See *Cadence.*

Melody. The agreeable effect of different sounds ranged and disposed in succession. The air of a tune.

Mezzo soprano. A high countertenor or low treble, having the E clef on the second line of the staff.

Minim. A character in rotation equal to two crotchets or half a semibreve.

Minor. See *Major.*

Mixed cadence. See *Cadence.*

Modulation. The regular progression of several parts through the sounds that are in the harmony of any particular key, as well as the proceeding naturally and regularly from one key to another.

Monochord. A Musical instrument to measure the variety and proportion of Musical sounds. It is constructed with a rule on which are sundry subdivisions, whereon is a string stretched upon two bridges at each end; between them is a movable bridge, by means of which, in applying it to the different divisions of the line, you find that the sounds are in the same proportions to one another as the divisions on the line cut by the bridge.

Mordente. A grace used by the Italian School, by turning upon the note without employing the note below.

Motion. The manner of beating the measure to accelerate or protract the pronunciation of the words or notes. It is this which distinguishes the different sorts of time.

Natural. A character ♮ used to contradict those flats or sharps that are placed in the signature on the same line or space whereon the natural is employed, in which case you must take the natural note as it is in the diatonic scale.

Notes. Characters which mark the sounds; that is, the elevations and depressions, and the swiftness and slowness of its motions. In strict propriety, however, the word only implies the marks which denote the degrees of gravity and acuteness to be given to each sound.

Obligato. It is used of a movement written for a particular instrument or voice.

Oblique motion. That in which one part repeats or holds on the same note, whilst the other moves up or down.

Octave. An harmonical interval, consisting of seven degrees or less intervals. It contains five tones and two semitones.

Organ point, or *Pedal point.* A series of chords, in some of which the harmony of the fifth is taken unprepared upon the bass as a holding note, whether preceded by the tonic or by the harmony of the fourth of the key.

Part. A piece of the score or partition written by itself for the convenience of Musicians: or it is one or more of the successions of sounds which make the harmony written apart.

Partitura, or *Partition,* the same as *Score,* which see.

Passage. A portion of an air or of a harmony, consisting at most of one, two, or three measures.

Passing notes. Graces, wherein small notes follow the larger ones to connect them with the succeeding note.

Pause. A character 𝄐 placed over a note to denote that the regular time thereat is to be delayed, and a long continuance made of the sound on that part of the bar.

Pedal harmonies. The same as *Organ* or *Pedal points,* which see.

Perfect cadence. See *Cadence.*

Phrase. A short melody which does not contain a perfect or satisfactory Musical idea.

Pianissimo. See *Piano.*

Piano. Placed over a movement to signify to be played softly and sweetly. *Pianissimo,* its superlative, denotes that it is to be played very soft.

Pitch. The degree of acuteness or graveness of a note. It is known from experiments that any noise whatever produced by a sonorous body, or by the vibrations of a string, which is repeated two hundred and forty times in a second at equal intervals, emits the sound of the tenor C; if three hundred and sixty, the fifth above. In two perfect unisons from two pipes each twenty-four inches long, each has two hundred and forty vibrations in a second, either alternate or coincident. In both cases the vibrations are not distinguishable from each other. What is called concert pitch is an arbitrary standard selected by Musicians, by which the tuning is guided, not very different from what we have above described.

Piu. A little more; it increases the strength of the word to which it is added. Thus *Piu allegro*, a little quicker. *Piu piano*, a little softer, &c.

Plagal melodies are such as have their principal notes contained between the fifth of the key and its octave or twelfth.

Plaint chant. Used in ancient Ecclesiastical Music to signify the chief melody which was confined to the natural sounds of the scale.

Poco. A little less, has just the contrary effect of *Piu*, and therefore diminishes the strength of the signification of the word to which it is annexed. Thus *Poco presto* means not quite so quick as presto requires. *Poco piu allegro*, a little more lively and brisk than allegro alone requires.

Point. A mark · used by many authors instead of the dash ǀ; but its principal use is to distinguish those notes from which an intermediate effect is required, different from the dash.

Post-positions are singular suspensions of the harmony, being the reverse of anticipations; they are, in fact, the retardations of harmony, by putting a discord upon the accented part of the bar, but not prepared and resolved according to the rules for discords.

Preparation of a discord. Taking care that the note which is the discord is heard in the preceding harmony.

Presto to a movement denotes that it is to be performed fast or quick, yet not with rapidity. The superlative *Prestissimo* is very quick. *Non troppo presto*, less quick, not too quick.

Quadrum. The same as *Natural*, which see.

Quaver. A measure of time equal to half the crotchet, or an eighth of the semibreve.

Quintuple. A species of time which contains five crotchets in a bar: but seldom used.

Radical bass. The same as the *Fundamental bass*, which see.

Repeat. A character 𝄋 to denote that what was last played or sung must be repeated or performed again: this is otherwise marked by dots against a bar, or by the words *Da capo* or *Bis*.

Resolution is the deciphering a canon, or perpetual fugue from a single line or staff, or in one part, in which all the voices that are to follow the guide or first voice are written separately, either in score, that is in separate lines, or in separate parts, with the pauses each is to keep, and in the proper tone for each.

Resolution of a discord. The descent of a discord after it has been struck either a tone or a semitone according to the mode.

Rest. A pause or interval of time, during which there is an intermission of the voice or sound. Rests are of various lengths, and accordingly expressed by certain characters according to the quantity of certain notes.

Rhythm. The disposition or arrangement of melody or harmony in respect of time or measure.

Rinforzando. Denoted thus > <, to signify that the sound is to be diminished and increased.

Ripieno signifies full, and distinguishes those parts that play now and then to fill up the Music from those that play throughout the piece.

Root. The prime or lowest note of the *Harmonic triad*, which see.

Scale. A series of sounds rising or falling towards acuteness or gravity from any given pitch of tune to the greatest practicable distance, through such intermediate degrees as make the succession most agreeable and perfect, and in which all the harmonic intervals are conveniently divided. This scale is denominated a universal system.

Schisma. An interval equal to about half a comma.

Score, or *Partition*. The Music of a piece written for all the several parts in their places under each other, and the bars scored or drawn in their proper places through the whole from top to bottom.

Second. An interval consisting of two degrees distant from each other one tone or one semitone; consequently there are two kinds of seconds, the major second, or tone, and the minor second, or semitone.

Segno. See *Al segno*.

Segue. It follows. A word often written before a part, which without stopping is immediately to follow the last note of the preceding movement. It is also used where minims, crotchets, &c. are subdivided by strokes drawn through their tails to make them abbreviated groups, to signify that they must be performed in the manner the first are marked.

Semibreve. A note of half the quantity of a breve, containing two minims, four crotchets, &c. The semibreve is accounted one measure of time, or the integer in fractions and multiples, whereby the time of the other notes is expressed.

Semidiapason. A defective octave, or an octave diminished by a minor semitone.

Semidiapente. A defective, false, or flat fifth.

Semidiatessaron. A defective fourth, properly called a false fourth.

Semiquaver. A note containing half the quantity of the quaver.

Semitone. Usually employed to denote a half tone, though it is not, mathematically speaking, the half of a tone. Semitones are moreover of three sorts, the greater, the lesser, and the natural semitone. The use of semitones is to remedy the defects of instruments, which, having their sounds fixed, cannot always be made to answer the diatonic scale.

Senza. Without: as *Senza stromenti*, without instruments.

Sequence. A similar succession of chords ascending or descending diatonically.

Seventh. A Musical interval consisting of three tones, two major semitones, and two minor semitones; at least such is the major seventh, but the minor seventh consists of one tone less. The seventh is composed diatonically of seven degrees and six intervals.

Sforzato. A term written over a note to signify that it is to be played louder than the rest.

Shake. A quick alternate repetition of the note above with that over which it is marked, and commonly ends with a turn from the note below.

Sharp. An artificial note or character thus ♯, which prefixed to a note shows that it is to be sung or played a semitone or half note higher than the note would have been without it.

Signature. The sharps or flats placed after the clef at the beginning of the stave which affect all the notes of the same letter throughout the movement. Those which alter the course of the movement in addition to the others being termed *accidental*, whereas the first mentioned are essential.

Sixth. One of the simple or original concords or harmonical intervals. It is of two kinds, greater and less, and therefore esteemed one of the imperfect concords, though each of them arises from a different division of the octave. The former is composed of six degrees and five intervals, in which four are tones and one a semitone. The lesser sixth is also composed of six degrees and five intervals, whereof three are tones and two semitones.

Skip. The passing from one sound to another by more than a degree at one time.

Slide. A grace used by the German School, consisting of two small notes which move by degrees.

Slur. An arch ⌒ drawn over two or more notes upon different degrees, and signifies that all the notes are to be played as smoothly as possible. In vocal Music it is placed over or under all the notes that are to be sung to the same syllable.

Smorzato. A term to denote that the bow of the violin is to be drawn to its full length, not with equal strength, but lighter and lighter on it by degrees till at last scarcely any sound is heard.

Soave, or *Soavemente*. To be played sweetly or agreeably.

Solfeggio. The system in which the several notes of the scale are distinguished by the syllables *ut*, or *do* of the Italians, *re*, *mi*, *fa*, *sol*, *la*, whose office is, by applying them to every note of the scale, to obtain a pronunciation with ease, and also that by them the tones and semitones of the natural scale may be better distinguished. This is obtained by the four syllables *mi*, *fa*, *sol*, *la*. From *fa* to *sol*, and *sol* to *la*, and from *la* to *mi*, are each a semitone, without noticing the greater or less tone, but from *la* to *fa* and from *mi* to *fa* only a semitone. If these be applied in the following order, *fa sol*, *la fa*, *sol la*, *mi fa*, they express the natural series from C, and if repeated, a second or third octave; and we can by them express the whole of the different orders of tones and semitones in the diatonic scale, *fa*, *sol*, *la*, still standing above *mi*, and below it the same inverted *la*, *sol*, *fa*, and one *mi* is always distant from another an octave, which cannot occur with any of the rest, because in ascending after *mi*, *fa*, *sol*, *la*, *fa* always come in, which in descending are repeated inversely. The use of this system is this:—The first step in learning to sing is to raise a scale of notes by tones and the semitones in their natural places an octave, and descend again by the same, and then to ascend and descend by skips, as thirds, fourths, &c., and to do the same whatever be the pitch of the scale. Now these notes being represented by lines and spaces to which the above syllables are applied, and the learner taught to name each line and space thereby, is the system of Solfeggio. By it we learn to time the degrees and intervals of sound expressed by notes on a line or space, or give words to Music to which none have been written by means of articulate sounds, but chiefly by an acquaintance with the degrees and intervals expressed by those syllables, we readily know the place of the semitones and the true distance of the notes.

Sollecito. Used to express that the piece is to be performed in a mournful manner. It also means with care and accuracy.

Sopra. See *Sotto.*

Soprano clef. The C clef used for the voices of females and children. In Italy and Germany it is the clef in general use for the harpsichord; when placed on the first line it is called simply the soprano clef, but if it be placed on the second line it is called the mezzo soprano.

Sostenuto denotes that the sound is to be held on in an equal steady manner.

Sotto. Below, inferior, in contradistinction to *Sopra* above.

Space. The void between any two lines of the staff whereon a piece of Music is pricked or noted. In ancient Music three spaces and four lines only were used.

Spirito, or *Spiritoso.* To be played with vigour or spirit.

Staccato denotes that the Music to which it is applied is to have every note divided or separated from the next in a plain and distinct manner.

Staff. The five lines on which, with the intermediate spaces, the notes of Music are written; said to have been introduced by Guido.

Stem. The notes of Music consist generally of two parts, the head and the stem; the former is either open or black, and must always be placed on a line or space, the stem is the line drawn from it either upwards or downwards at pleasure.

Subdominant. The fifth below the key note, or fourth in ascending, being as it were the governing note, because it requires the tonic to be heard after it in the plagal cadence.

Subito. Quick, hastily; thus *Volti subito,* an Italian phrase written at the bottom of a leaf, means turn the leaf quickly.

Submediant, or middle note between the tonic and subdominant descending; it is the greater sixth in the major scale, and the lesser sixth in the minor scale.

Subsemitone. A word used by the Germans for the leading note or sharp seventh of the scale.

Substitution, Chords of. Names given to the two chords of the ninth major and minor.

Superdominant. The sixth of the key in the descending scale.

Supertonic. The second above the key note. In theory, it is considered a variable sound, being a comma higher in the major scale than in its relative minor.

Supposed bass. That bass in which the root of the harmonic triad of the chord is not the lowest note; by others it is called the inversion of the accompanying chord.

Supposition. The use of two successive notes of equal value as to time, one of which being a discord supposes the other a concord. There are several kinds of supposition: first, when the parts proceed gradually from concord to discord, or on the contrary, from discord to concord, the intervening discord serving merely as a transition to the following concord.

Suspension. The holding on of a note.

Syncopation. A striking or breaking of the time whereby the distinctions of the several times or parts of the measure is interrupted. But it is more particularly used for the connection of the last note of a bar with the first of the following one, so as to make only one note of both; and it is also sometimes used in the middle of a measure, likewise when a note of one part ends or terminates in the middle of the note of another; this is, however, also called binding or ligature. Syncopation is also used for a driving note; that is, when some shorter note at the beginning of a measure, or half measure, is followed by two, three, or more longer notes before any other occurs equal to that which occasioned the driving note to make the number even, thus when an odd crotchet comes before two or three minims, or an odd quaver before two or more crotchets.

Syncope. Signifies the division of a note; employed when two or more notes of one part answer to a single note of one or the other, as when the semibreve of the one answers to two or three notes of the other.

System. A compound interval, or one composed or conceived to be composed of several less; thus the octave is a system. See *Diastem.*

Tablature. The use of letters of the alphabet, or any other characters, to express the sounds or notes of a composition. It is not usual in modern Music. In a stricter sense, it is the method of writing Music for a particular instrument on parallel lines each of which represents a string of the instrument. On these certain letters of the alphabet are placed, whereof A shows that the string is to be struck open, B that a finger is to be put upon the first stop, C on the second, D on the third, and so on through the octave.

Tacet. Signifies that the part to which it is prefixed is to be silent.

Tardo. Slow, much the same time as largo.

Tasto. The touch of any instrument by means of which its notes are made to sound. The words *Tasto solo* are put to thorough basses, to denote that the instruments accompanying are merely to strike the single sounds from that place till they find figures again, or the word *accords* or *accompaniments* placed in their part which intimate that there the chords are to be begun.

Temperament. The arrangement of the imperfect concords in instruments whose keys are fixed by transferring to them part of the beauty of the perfect, or in other words, by subdividing the redundant comma so as to distribute it over the scale.

Tempo. Merely the Italian word for time. For *Tempo d'imbroglio,* see *Imbroglio.*

Tenor. The first mean or middle part, which is the ordinary compass of the human voice when neither raised to a treble nor depressed to a bass. It is denoted by the C clef on the fourth line.

Tenth. An interval consisting of nine degrees and five spaces.

Tetrachord. In ancient Music, a concord consisting of three degrees or intervals, and four terms or sounds, formerly called diatessaron. The octave has been considered as composed of two fourths which are disjoined or separated by a tone. Theory, however, does not allow the perfect mathematical equality of the fourths in respect to the places of the tones which compose them.

Thesis. The depression of the hand in beating time.

Third. An imperfect concord resulting from a mixture of two sounds containing two degrees or intervals, and three terms or sounds. It is of two sorts, major and minor; the first is composed diatonically of three terms or sounds containing two degrees or intervals on fixed instruments, and the minor third is composed of three degrees, and contains a tone and a diatonic semitone between the extremes.

Time. The duration or continuity of a sound or note as to its proportion of a bar or measure.

Tone. A certain degree or interval of time whereby a sound may be raised or depressed from one extreme of a concord to another. Tones arise out of the simple concords and are equal to their differences.

Tonic. The key note, or chief sound, upon which all regular melodies depend and with which they all terminate. All its octaves above and below are called by the same name.

Transition. The breaking a greater note into a less to smooth the roughness of a skip by a gradual passage to the following note.

Transposition. The change of a melody into a higher or lower pitch. Any melody in a major scale may be transposed into any other major scale by altering the signature according to the pitch of the new key. The same may take place with melodies in minor keys. When, however, a melody originally major is performed in the relative minor key, it is called variation and not transposition.

Treble. The highest or acutest part of the human voice, usually sung by females or by children.

Tremando and Tremolo. To denote that several notes of the same degree or pitch of tune are to be executed with one draw of the bow so as to produce an effect of shaking.

Triad. See *Harmonic triad.*

Triple. One of the kinds or measures of time, of which there are many species, but in all of them there is a division of the measures into three parts; as for instance, into three minims, three crotchets, three quavers, and so on. Three, or its multiples, being always the denominator of the fraction placed after the signature at the beginning of the staff.

Triplets. Groups of three notes each grouped by uniting the stems at the bottom.

Tritonus, or *Tritone.* An interval consisting of three tones, or a greater third and a tone major, which tone is divided into two semitones, one major the other minor. The tritone is a sort of redundant third, consisting of three tones, whence its name; or more properly of two tones and two semitones, one greater and one less, as from C to F♯ or E to B♮. It is not, in truth, as it is often erroneously called, a greater or sharp fourth, because the fourth is a perfect interval, and has no majority nor minority, nor must it be confounded with the defective fifth, inasmuch as the tritone only includes four degrees, whereas the defective fifth contains five, besides which, among the six semitones which compose the tritone chromatically, there are three greater and three less, whereas in the defective fifth there are two less and four greater semitones.

Tie. An arch ⌒ drawn over two notes on the same degree.

Tune. That property of sounds whereby they come under the relation of acute and grave towards each other.

Turn. A grace ∽ marked over a note which indicates that a note one degree higher is to be struck before it shortly, and passing quickly through the note itself, turn from the note a degree below into the note itself.

Tutti. As opposed to *solo,* in which only one part plays, means that all the parts are to play together.

Uncommon chord. The chord of the sixth, not so called because unusual or improper, but in contradistinction to the common chord, or that or which the lowest note is the fundamental bass.

Unison. The effect of two sounds equal in degree of tune or in point of gravity and acuteness. Or a consonance of two sounds produced by two bodies of the same matter, length, thickness, tension, &c. equally struck so that they yield the same tune or sound.

Ut. The name of the first of the Musical syllables, to which the French added a seventh, which is called *si.*

Variation. See *Transposition.*

Veloce. Quick, nearly the same as *Vivace.*

Vigoroso. Denotes that the movement is to be performed with vigour and strength.

Vivace. With life and spirit. It is a degree of movement between largo and allegro, but nearer to allegro than largo.

Volti. See *Subito.*

LIST OF SOME OF THE CHIEF WORKS ON MUSIC.

A. D.
1474. Tinctor Terminorum Musicæ Definitorium, Naples.
1480. Gafurius, (Franchinus,) Theoricum opus, 1480, 1492; Practica Mus. 1496, &c.; Harmonica, 1500.
1482. Ramis, (Bartholomeo de Pareia,) De Musicâ Tractatus, Bononiæ.
1487. Burtius, (Nicolas,) Musices Opusculum, Bononiæ.
1503. Boetii Opera, B. L. fol. Paris.
1512. Wollicus, (N.,) Enchiridion Musices, Paris.
1516. Aron, (Pietro,) Institutio Harmonica, Bononiæ.
1529. Rossetti, (B.,) de Rudimentis Musices, &c. Verona.
1533. Vanneo, (Stephano,) Recanetum de Musica Aurea, Roma.
1547. Glareanus, (Hen. Lor.,) Dodecachordon, Basil.
1555. Thyard, (Ponce de,) Solitaire Second, ou Prose de la Musique, Lyons.
1557. Euclidis Rudimenta Musices Gr. et Lat. Parisiis.
1558. Zarlino, (Giuseppe,) Institutioni Harmonichi, Venet. fol.; also in 1562, 1573, 1589; Dimostrazioni, 1571, 1589.
1563. Sebastiani Bellum Musicale, Argent.
1571. Nicolaus, (Elias,) Orgeloder Instrument Tabulatur, Leipzig.
1577. Salinas, (Franciscus,) De Musica, fol.
1581. Galilei, (V.,) Dialogo della Musica, Fiorenze.
1582. Yssandron, (Jean,) Traité de Musique Pratique, Paris.
1596. Zacconi, (F. L.,) Prattica di Musica, Venet. fol.
1597. Morley, (Thomas,) Introduction to Music, 4to., Lond.
1604. Reinhard, (Andreas,) Musica, small 8vo. Lipsiæ.
1609. Ornithoparcus, (Andreas,) Micrologus, translated by Dowland.
1612. Viadana, (Ludovico,) Opus Musicum Sacrorum Concentuum.
1613. Cerone, (R. D. Pietro,) El Melopeo y Maestro, Napoles.
1627. Mersenne, (Martin,) under the name of De Sermes, Harmonie Universelle, 8vo.
1630. Bartoli, (P. D.,) Del Suono de' Tremori Armonici e dell' Udito, Bologna.
1631. Picerli, (Silverio,) Specchio Secondo di Musica, Nap.
1636. Butler, (Charles,) Principles of Music, small 4to. London.
1648. Doni, (Gio. Battista,) Annotazioni sopra il compendio, 4to. Roma.
1650. Kircher, (Athanasius,) Musurgia Universalis, fol. Roma.
1652. Meibomius, Antiquæ Musicæ Auctores, 2 vols. 4to. Amst.
1652. Matthai, (Conrad,) Bericht von den Modis Musicis, Kœnisberg.
1656. Descartes, Musicæ Compendium, Amst.
1658. Gassendi Miscellanea Manuductio ad Theorem Mus., fol. Lug.
1664. Alstedius, Templum Musicum, by Birchensha.
1665. Playford, (John,) Introduction to the Skill of Music, 8vo.
1666. Rossi, (Lemme,) Sistema Musico, 4to. Perugia.
1667. Simpson, (Christopher,) A Compendium of Practical Music, 8vo. London.
1668. Bononcini, (M.,) Musico Prattico.
1670. Mengoli, Speculationi di Musica, Bologna.
1672. Lorente, El Porque de la Musica, fol. Alcala.
1672. Salmon, (Thomas,) Essay to the Advancement of Music, Lond.
1676. Mace's Musick's Monument, fol.
1678. Smith's (Theod.) Musical Directory.
1682. Ptolomæi Harmonicorum, lib. iii. Gr. et Lat. 4to. Oxonii.

A. D.
1685. Scaletta, (H.,) Scala di Musica, fol. Roma.
1687. Berardi, (Ang. da S. Agatha,) Documenti Harmonici, 4to. Bologna.
1694. Holder, (Dr. William,) A Treatise on the Natural Grounds and Principles of Harmony, 8vo.
1695. Bontempi, (Gio. And. Arg.,) Historia Musica, fol. Perugia.
1696. Prinz, (W. C.,) Satyrischer Componist, 4to. Dresden.
1698. Fokkerodt, (John Arnold,) Musikalischer Unterricht Mühlhausen, part ii. 1716, part iii. 1718.
1698. Loulie, Elémens ou Principes de Musique, Amst.
1701 Janowka, (Thos. Balthazar,) Clavis ad Thesaurum Magnæ Artis Musicæ, Alt. Prag.
1706. Tevo, (Zacharia,) Il Musico Testore, 4to. Venezia.
1708. Gasparini, (Francesco,) L'Armonico Prattico al Cimbalo, Ven.
1710. Henfling, (Conrad,) Specimen de novo suo Systemate Mus., in the Berlin Miscellany, vol. i. part iii. p. 265—294, 4to.
1713. Mattheson, (John,) Orchestre der Vollkommene Kapellmeister, fol. Hamburg.
1721. Malcolm, (Alex.,) A Treatise on Music, 8vo. Edinburgh.
1722. Bonnani, (F.,) Gabinetto Armonico.
1722. Rameau, (Jean Phil.,) Traité de l'Harmonie, 4to. Paris.
1724. Turner, (William,) Sound Anatomised in a Philosophical Essay on Musick, Lond.
1725. Fux, (John Joseph,) Gradus ad Parnassum, fol. Vienna.
1725. Chateauneuf, Dialogue sur la Musique des Anciens, 12mo. Paris.
1731. Pepusch, (John Christopher,) A Short Treatise on Harmony, oblong 8vo. Lond.
1732. Walther, (John,) Gottfried Musikalische Lexicon, 8vo. Leipzig.
1735. Burette, (P. J.,) Dialogue de Plutarque, trad. du Grec, 4to.
1737. Lampe, (John Fred.,) Method of Teaching Thorough Bass, 4to. Lond.
1739. Euleri tentamen novæ Theoriæ Musicæ, 4to. Petrop.
1740. Grassineau, (James,) A Musical Dictionary, 8vo. London.
1741. Le Beuf, (L'Abbé,) Traité Historique et Pratique sur le Chant Ecclésiastique, 8vo. Paris.
1742. Blanchini de Instrumentorum Musicæ Veterum, Rom.
1743. Bourdelot, Histoire de la Musique, 4 vols. Frankfort.
1746. Tansur, (Wm.,) Musical Grammar, Lond.
1749. Geminiani, (Francesco,) Treatise on Good Taste, fol.
1749. Smith, (Dr. R.) Harmonics, or Philosophy of Sounds, 8vo. London,
1752. D'Alembert, (Jean le Rond,) Elémens de Musique, Paris, Lyons, 1762.
1753. Avison, Essay on Musical Expression, 8vo. Lond.
1753. Bach, (Charles Philip Emanuel,) Versuch über die wahre Art das Clavier zu spielen, 1753, 1759, 1780.
1754. Bethisy, (M. de,) Exposition de la Théorie, &c. 8vo. Paris.
1754. Riepel, (Joseph,) Anfangsgründe, &c. fol. Ratisbon.
1754. Tartini, (Giuseppe,) Trattato di Musica, 4to. Padua.
1755. Nichelman, (Christopher,) Die Melodie, 4to. Dantzig.
1755. Marpurg, (Fred. Wm.,) Handbuck bey dem General Bass, 1757, 1762.
1758. Adlung, (M. Jacob,) Anleitung au den Musikalischer Gelahrtheit, 8vo. Erfurt; new edition, 1783, by Hiller.
1761. Antoniotto, (Giorgio,) L'Arte Armonica, fol. London.

A. D.

1764. Roussier, (M. l'Abbé,) Traité des Accords, 8vo. Paris.

1767. Blainville, Histoire Générale de la Musique, Paris, 4to.

1768. Rousseau, (Jean Jaques,) Dictionnaire de Musique, Paris.

1770. Holden, (John,) An Essay towards a Rational System of Music, oblong 4to. Glasgow.

1771. Bemetzrieder, Leçons de Clavecin, et Principes d'Harmonie, 4to. Paris.

1773. Sulzer, (John George,) Allgemeine Theorie der Schönen Kunste, large 8vo. 2 vols. Leipzig.

1774. Leags Clavier Spielen und General Bass, Osnabruck.

1774. Eximeno, (D. A.,) Dell Origine e delle Regole della Musica, 4to. Rom.

1774. Gerbert, (Martin,) De Cantu et Mus. Sacra, 4to. 2 vols.; Script. Ecclesiastici, 4to. 3 vols, Typ. San Blas.

1774. Kirnberger, (John Philip,) Die Kunste des Reinen satzes, 4to. Berlin.

1774. Martini, (Il Padre Giambattista,) Saggio di Contrappunto, &c. 2 vols. 4to. Bologna.

1776. Hawkins, (Sir John, Knight,) A General History of the Science and Practice of Music, 5 vols. 4to. Lond.

1776. Burney, (Charles, Mus. Doc. Oxf.,) A General History of Music, 4 vols. 4to. 1776 to 1789, London.

1776. Mercadier, (De Belesta,) Nouveau Système de Musique, 8vo. Paris.

1779. Vallotti, (Franc. Ant.,) Scienza Teorica e Pratica della Moderna Musica, 4to. Padova.

1780. Hiller, (J. A.,) Musikalische Richtigen Gesange, 4to. Leipzig.

1780. Borde, (M. de la,) Essai sur la Musique, 4 vols. 4to. Paris.

1781. Catalisano, (Genaro,) Grammatica Armonica, Roma.

1782. Petri, (John Samuel,) Anleitung zur Pratischen Musik, 4to. Leipzig.

1782. Maxwell, (Mr.,) Essay on Tune, 8vo. London.

1782. Pizzatti, (Giuseppe,) La Scienza dei Suoni, small 8vo. Venice.

1784. Jones, (Rev. Wm., of Nayland,) A Treatise on the Art of Music, Colchester.

A. D.

1784. Keeble, (John,) The Theory of Harmonics, 4to. London.

1789. Turk, (Dan Gottlieb,) Klavierschule, Leipzig.

1791. Framery, (Nicolas Etienne,) Encyclopédie Méthodique, 3 vols. Paris, 1791 to 1818.

1793. Frike, Guide in Harmony, oblong fol. Lond.

1794. Sala, (Nic.,) Regole del Contrapunto Pratico, fol. Napoli.

1795. Harrison, Universal Dictionary of Music.

1796. Gretry, Mémoires, ou Essai sur la Musique, 3 vols. 8vo. Paris.

1796. Kollman, (A. C. F.) Essay on Musical Harmony, fol.

1798. Requeno, (Vinc.,) Saggi sul Ristabilimento dell' Arte Armonica dè Greci e Romani Cantori, Parma.

1799. Kollman, Essay on Musical Composition, fol.

1800. Shield, (William,) Introduction to Harmony, 4to. London.

1800. King, (M. P.) General Treatise on Music, particularly on Harmony or Thorough Bass, and its application in Composition, fol. Lond.

1801. Langle, (H. F. M.,) Nouvelle Méthode pour chiffrer les Accords, 8vo. Paris.

1802. Koch, (Hen. Christ.,) Musikalisches Lexicon, 2 vols. large 8vo. Frankfort.

1802. Kalkbrenner, Histoire de la Musique, 8vo. Paris.

1802. Sabbatini, (Quigi,) Trattato sopra le Fughe Musicali, 2 vols. 4to. Venezia.

1802. Catel, Treatise of Harmony.

1803. Gunn, (Mrs. Anne, late Miss Young,) Introduction to Music, 8vo. Edinburgh.

1806. Momigny, Cours complet d'Harmonie et de Composition, d'après une Théorie Nouvelle, 3 vols. 8vo. Paris.

1808. Choron, (M.,) Principes de Composition des Ecoles d'Italie, trad. de l'Italien de Sala et autres, 3 vols. 4to. Paris.

1809. Callcott, (Dr.,) Musical Dictionary, small 8vo. London.

1812. Crotch, Elements of Musical Composition.

1814. Choron, (M.,) Méthode Elémentaire de Composition, trad. de l'Allemand d'Albrechtsberger, 2 vols. 8vo. Paris.

1816-17. Berton, (H. Montan,) Traité d'Harmonie, suivi d'un Dictionnaire des Accords, 4 vols. 4to. Paris.

ENGRAVING.

Definition of Engraving, and earliest Methods of the Art.

ENGRAVING is an Art allied to Sculpture as well as to Painting, but more especially to the latter, ever since the invention of multiplying impressions upon paper. In its ancient and more general sense, Engraving may be defined the representation of objects by means of incision on plates of metal, on planks or blocks of wood, The Art defined. on stones, gems, &c. Modern language gives the name more commonly to such lines and characters executed by incision upon wood or metal, as are intended to be communicated to paper in a printing-press; and applies to the impressions thus taken the term prints or Engravings. The same term is used for lithographic impressions, while those taken from wood are sometimes called wood-cuts.

The word Engraving, however, is still used according to its primitive meaning, to denote certain branches of the Art which, from their utility, as well as from their hold upon the vanity of mankind, are never likely to be lost, and which have descended to us from the remotest antiquity, such as Gem Engraving, Seal Engraving, and Die Engraving.

Its antiquity.

(1.) As an introduction to the present subject, some notice may be expected to be taken of these antecedent and partly sculptural inventions. Their origin belongs to the earliest date of human civilization, and they doubtless led the way in contributing to suggest further discoveries; until, in fulness of time, that of Printing burst forth, meteor like, upon the world, and seemed to render every other light or key to knowledge dim, subordinate, and comparatively inoperative. We must content ourselves however with referring to the words CAMAIEU and INTAGLIO in our *Miscellaneous Division*; and with adding here only a few particulars as to the method by which the Gem Engraver proceeds, and the instruments with which he works. Whether, according to the opinion of Winkelmann, or of his ingenious contemporary Natter, (in a Treatise *De la Méthode Antique de graver en Pierres fines comparée avec la Méthode Moderne*, Lond. 1754. fol.) the tools of modern artists are similar to those used in ancient Art, may be still a question. But there can be no doubt that, in order to clear ideas on the subject of this or any other Art, some acquaintance with the mechanical means and implements employed is absolutely requisite.

Gem Engraving.

(2.) After the stone or other material has been shaped and polished, the outline is drawn on the upper or convex side * with a brass needle or with a diamond; and the underside is fastened by a cement of mastic to a wooden handle in such a manner as to be held with ease in any direction, and applied with accuracy to the different tools for cutting it. The first of these which we select for explanation is a cylindrical tube, (see plate i. fig. 1,) of which the sharpened extremity at A is used for describing circles and for perforating. The other extremity B C is a triangular prism made to be inserted horizontally into the axis of a revolving piece of steel, called a mill, which is kept in rotatory motion by means of a common lathe. Fig. 2 is another tool furnished at one end with a knob or round button, and having the other constructed like the last for insertion in the mill, and for revolving also on the same horizontal axis. The French name for this tool is *boute rolle*. By varying the form of the button at D, (fig. 2,) other tools are produced. In some the button takes a disk-like form, rounded at its edge. (Fig. 3.) In others the disk is square at its edge, (fig. 4,) and in others sharp. (Fig. 5.) To the latter instrument the French give the name *scie*. It resembles, in fact, a small circular saw.*

(3.) Fig. 6 gives an illustration of the manner in which the stone or gem is applied to the tool while the latter, previously dipt in a mixture of diamond-powder with olive-oil, is kept in revolution by the lathe. The larger tools are employed for the commencement, and the smaller for finishing. Seal Engraving. Care must be taken at all times in working seals or intaglios, not to place the stone in such a direction against the tool that the upper portion of the excavated work may overhang in any the slightest degree the parts below intended to be prominent in the impression. No proper impression can, in such a case, (causing what Italians call *sotto quadro*,) be produced.†

(4.) For a description of the various materials upon which the Gem Engraver exercises his Art, we refer to MINERALOGY in the *Second Division* of this Work; and only remark here, that the stone called carnelian (sarda)

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* A convex surface is preferable, since it presents a deeper mass towards its centre, where the principal (and in the intaglio more prominent) objects are to appear. (See PAINTING, Art. 262. No. 2.) The process of shaping and polishing is the business of the lapidary; but the Gem Engraver must, we need scarcely observe, be competent not only to design, but also to model his subject perfectly, and with all its due proportions in clay or wax before commencing the operation above described.

* The size and form of these instruments are of course accommodated by the artist to the several kinds of incision or excavation to be made. Sometimes the extremity D (fig. 2 to 5) is so small as to be scarcely distinguishable by the naked eye. When a tool of a different size or shape is required, the end B C (fig. 1) of the tool in use is drawn out from the mill, like the removable leg of a pair of compasses, and another instrument inserted in its place.

Beckmann observes that the ancient Greek artists formed upon glass both raised and engraved figures, though it is probable that many pieces of glass may have been moulded like paste: for that Art also is of very great antiquity. He refers to two ancient glasses found at Nismes, and described by Caylus, in his *Recueil d'Antiquités*, ii. p. 363, as having figures and ornaments cut upon them. If, says he, we can believe that learned Engraver and Lapidary, the celebrated Natter, the Ancients employed the same kind of instruments for this purpose as the Moderns. They undoubtedly had, in like manner, the wheel which writers term a lapidary's wheel, and which moved round on a horizontal axis above the work-table. If this conjecture be true, he adds that it explains, very intelligibly, a passage in Pliny respecting the various ways of preparing glass. *Aliud flatu figuratur, aliud* TORNO *teritur, aliud argenti modo cælatur*, lib. xxxvi. 26. p. 758.

† When the work is completed, the Engraving is next polished, by being brought in contact with boxwood tools, kept in rotatory motion, like the others, by the mill, and dipped in emery or tripoli-powder wetted, or in rotten stone. These polishing instruments are sometimes of pewter or of copper; and sometimes consist of hair brushes affixed to wheels, such as fig. 3 or 4, for the purpose.

was a favourite material with the best Engravers of antiquity, since it combined the most delicate and yielding texture with sufficient hardness and with susceptibility of exquisite polish. The same qualities, of course, continue to recommend it, although with respect to polish, antique gems far exceed the utmost efforts of modern workmanship.[*] The Ancients frequently used ivory also for Cameo Engraving: but none of these works remain to us.

Die Engraving.

(5.) For Die Engraving the process assimilates partly to that for engraving seals, and partly to that for relievo or raised work. The first operation of the artist is to engrave his punches or puncheons, one for each side of the medal, medallion, or coin to be struck. The piece of steel, or of iron mixed with steel called a punch has the intended figure either of a head, or of a reverse engraved in relievo upon it before it is tempered and hardened.

(6.) When this Engraving, or steel cameo is completed by means of chisels, flatters, gravers, &c. (Art. 2.) the punch is tempered, and under it is placed another piece of steel (but in a soft state) called the die, out of which the future matrix, the future *creux*, is to be stamped or hollowed. The punch must be tempered very highly that it may be enabled to bear the blows of the hammer, and the cube or die (*talus*[†]) is made red hot the better to receive the hollow impression. But the matrix to be complete, requires next its several impressed cavities to be sharpened and retouched; and this is done by the graving instruments (Art. 2.) before mentioned.[‡]

ines cut ith the raver, ometimes ft open.

(7.) Another exercise of the Engraver's Art, perhaps quite as ancient as the foregoing, and frequently combined with it, was that practised by the Egyptians,[§] of which Strutt notices some hieroglyphical remains preserved in the British Museum. He alludes to an alto relievo in brass representing Isis. "The flat part, or ground of the relief," he observes, "together with the bottom edges and back part of it, are ornamented with figures and symbolical characters, executed entirely with the graver, without any other assistance. The backs of the crocodiles" (on which the Goddess appears standing) "and the heads of the four-footed animals," (one of which she holds in each hand,) "are also finished with the same instrument in a very careful manner."[*]

Sometimes filled up with other metal, or with niello.

(8.) To the practice of cutting lines with the graver, was superadded a further process of very great antiquity; that of filling in the lines or excavated parts with some metal of a colour different from that of the engraved plate. Under this variety of the Art may be classed the method called working in niello, practised among the goldsmiths of Europe in the Age of Finiguerra, at the era of the discovery of printing.[†] The conceit of inlaying one metal with another finds employment for numbers at the present day in Russia, whence we derive continual specimens in the form of knife-handles, snuff-boxes, &c. Sometimes more than two metals are introduced. Evelyn, and after him Strutt, among other authorities for the antiquity of Engraving, quotes the word קלצ, *kalaugh*, which is used in 1 *Kings*, ch. vi. ver. 35. to express the hollowing out of the carved work upon the cherubim, palm trees, and open flowering in the sanctuary, which were afterwards *filled up* with gold.[‡]

(9.) A description of Engraving in niello is thus given by the Count Seratti. "The intended subject was engraved with a burin upon a plate of silver. This was afterwards covered over with niello, (*nigellum*,) which was a metallic substance, or black kind of enamel, reduced to powder, composed of silver, copper, lead, sulphur, and borax, so that it was more easily fusible than silver, and of a dark colour. The necessary degree of heat was then applied, which melting this metallic compound without affecting the silver plate occasioned it to run about until it had filled all the strokes of the Engraving. Lastly, the superfluous part of the niello which rose above the surface of the silver plate was removed by scrapers, files, and pumice-stone, until the even surface of the plate appeared in every part so that the niello only remained in the strokes made by the burin, thus giving to the engraved design its true effect."[§]

(10.) From the very remote antiquity of this and the foregoing branches of the Art, (see *Miscellaneous Division* for the words CAMAIEU and INTAGLIO,) it is quite plain to us that the Ancients possessed all the materials (however rude and unartist-like some of their attempts[||] may seem) for arriving at the same results

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[*] The union of white carnelian (or chalcedony) with red, (see *Miscellaneous Division*, CARNELIAN,) or brown in the same stone has given frequent exercise to all that taste and ingenuity could effect in Gem Engraving. Differently coloured strata, or zones, have been sometimes found so united by nature in one gem as to assist in the happiest manner the purposes of the Cameo Engraver. If, for instance, a white, semi-transparent layer be found above a red layer of carnelian; this red ground will impart a delicate flesh tint to a face executed in raised work out of the white surface. Again, if a stratum of white be situated between one of red and brown, or between one of red and any other colour, the brown, or other colour may be converted, with pleasing effect, into drapery, animals, chariot-wheels, &c. In some extraordinary gems of this kind no less than four different layers are seen distinctly formed, of each of which the artist has effectually availed himself by accommodating his design to the caprice of Nature.

[†] Skinner derives *talon* (claw of a bird of prey) from *talus, quia precipuum istarum avium robur in* talo *seu calcaneo consistit.* If this etymology be admitted, the derivation of the Italian words *intaglio* and *intagliare* will be found in the action of the bird's foot *clawing* the earth, or scraping, scratching, and *cutting* into any object.

[‡] See Note (A.) at the end of Engraving.

[§] Strutt brings the Art from Egypt into Phœnicia, and thence to Greece, where in Homer's time, as we learn from the shield of Achilles, it must have been most successfully and tastefully cultivated. But the palm of excellence, prior to either Egyptian, Phœnician, or Grecian Art, has been conceded to Etruria. Out of the Etruscan antiquities for which the British Museum is indebted to Sir William Hamilton, Strutt, in his Dictionary, gives two engraved specimens extremely curious.

[*] See Note (B.) at the end of ENGRAVING.

[†] The Abbé Lanzi (*Storia Pittorica*, vol. i. p. 130.) calls Engraving in niello, *artifizio antichissimo frequentato nel secolo* xv, *specialmente in Firenze, caduto in dimenticanza, nel susseguiente malgrado le diligenze del Cellini per mantenerlo.* He then goes on to show its uses. It was employed for the embellishment of all movables in silver, as well objects of sacred value, chalices, missals, and other books of Religion, depositories of relics and paxes,—as for profane purposes, upon sword handles, armour, table services of plate, bracelets, and other ornaments of dress. It was also much in vogue for a sort of cabinets of ebony, adorned in different ways, with small images in silver, and small plates tastefully worked in niello, representing historical groups of figures or wreaths of flowers.

[‡] Evelyn's *Chalcography*, p. 18, and Strutt's Essay *On the Origin and Progress of Engraving*, p. 8, at the end of vol. i. of his *Dictionary of Engravers.*

[§] Cellini (*Trattato del Oreficeria*, cap. ii. p. 24.) remarks upon the great care to be taken in cleansing the plate previously to the application of the niello. The plate was to be purified from all grease and dirt by an operation termed among goldsmiths *la cenerata, i. e.* boiled in clean water mixed with oak ashes for a quarter of an hour, then taken out and thoroughly washed in clean water with a small brush.

See a Dissertation by Count Seratti on the sulphur in his possession, a Work of Maso Finiguerra, quoted by Mr. Ottley, p. 270 of his *History of Engraving.*

[||] Strutt has engraved from the Hamiltonian collection of Etruswith their modern glyptic followers, who have not unfrequently claimed the honour of original discovery for what more justly might be termed sagacious adaptation.*

Of Prints.

The first prints were impressions from wood.

(11.) The earliest engraved works intended for impressions in ink were of wood. The Art of printing BLOCK BOOKS, (so called from each page being printed from one block,) long practised by the Chinese, appears to have travelled Westward to Europe, along with the introduction of the silk-worm, the invention of playing cards, &c., or perhaps even of gunpowder and the magnet, and to have been adopted by the monks of the XIIth Century for diffusing their religious tenets in pictures, just as, throughout the Dark Ages, they invented godly plays, called Mysteries or Moralities, to rival the *drami profani* of the minstrels, mummers, (*mimi*,) or bards.† Together with these pictures of Saints, and sacred events, short legends in verse, or appropriate passages from Scripture, were engraved upon the same block. When afterwards other means and other substances were tried, the varieties of mechanical execution and of pictorial effect increased in proportion.

(12.) M. Adam Bartsch, author of the *Peintre Graveur*, a Work of great value to collectors, in twenty-one octavo volumes, enumerates thirteen classes of Engraving.

Engraving. Its varieties.

1. Chalcography, or Engraving, properly so called,‡ executed with a graver.
2. Engraving with the dry-point.
3. Etching.
4. Etching finished with the graver.
5. Dotting or stippling, performed with a punch (*mit der goldschmits punze*) and mallet.
6. Scraping, or the dark method called mezzotinto, practised chiefly in England.
7. Engraving in different colours, or Le Blon's method.
8. French method or chalk Engraving.
9. English method by dotting. (*La manière pointillée.*)
10. Method for giving the effect of bistre, or Indian ink. (*Aquatinta, ou la manière de bistre.*)
11. Method by coloured washes. *Manière (à l'aquatinta) de lavis de différentes couleurs.*§
12. Xylography,* or Wood Engraving, (*Gravure en bois*,) and its varieties.
13. Lithography and its varieties.†

Modern Methods.

Three branches of Engraving.

The above enumeration, while it shows our subject to be of such extent as must be our apology for giving no more than a very brief account of each process, suggests, at the same time, an improved arrangement, which we propose to follow. Three sorts of material are here spoken of; *wood*, *metal*, and *stone*. We consequently divide the Art into three branches, XYLOGRAPHY, CHALCOGRAPHY, and LITHOGRAPHY. And the modes of operating upon each material are twofold, *viz.* either,

1. By some one of the varieties above-mentioned, (particularly Nos. 1, 2, 3, 12 and 13.) To this mode we give the name of *simple* process. Or,

2. By a union of two or more varieties. For this we propose the title of *mixed* or *compound* process.

In Wood Engraving, for example, by simple process we would be understood to mean the use of only one block for one complete impression. By compound process we imply the use of two or more blocks; or of some additional apparatus, such as was required in the infancy of the Art, for the completion of a print by stensilling.‡ In Chalcography, or Engraving on metal, we call each of the first three methods in the above list a simple process; while to almost all the remainder (namely, from No. 4 to No. 11 inclusive) we give the epithet of compound. And lastly, in the case of Lithographic prints, we would term that a simple process where only one stone or slab is required: but call the use of two or of several by the title of compound Lithography.

Engravers have certain principles of Art in common with Painters.

(13.) But before we undertake to trace to their origin, and to particularize the different methods and materials of Engraving in reference to ink-impressions upon paper; it will be proper to state some general rules to which every branch of the Art must alike be subject.

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can antiquities in the British Museum two extremely curious and valuable specimens of ancient Engraving. They form a frontispiece to the Ist Volume of his *Dictionary of Engravers*. One of them is part of the sheath of a parazonium or dagger. The original is eight inches and a half long, more than three wide at the top, and decreases gradually to an inch and a quarter at the bottom. Two historical subjects, of exceedingly rude workmanship, supposed from the *Iliad*, are engraved upon it. The figures are executed with the graver only upon a flat surface, and need only to be filled with ink and run through a printing-press, provided the plate could endure the operation to produce a fair and perfect impression. The other specimen, observes Mr. Strutt, is greatly superior in workmanship to the former. It is a patera, or instrument used by the priests in their sacrifices. Under each of the two figures upon it is an inscription in the Etruscan character; the figures are carved in low relief, but the hair of the woman, the ornamental parts of the drapery, and the smaller folds, are evidently the work of the graver only. M. D'Ankerville's eulogium on this relic is, that it is the richest and most remarkable remnant of antiquity, and of all the Etruscan bronzes, the best executed and most happily preserved.

* See Note (C.) at the end of ENGRAVING

† See our *Miscellaneous Division* for the words BARD, MINSTREL, MUMMER.

‡ From χαλκὸς, copper, and γράφω, I inscribe.

§ All these effects, including those of the preceding nine methods, are now as completely and almost as easily practicable from steel plates as from copper.

* From ξύλον, wood, and γράφω, I inscribe. The propriety of the term Wood Engraving has been disputed by some *chalcographers*, who, with a view to distinction as cutters of copper, prefer the term wood-cutting. But besides that the graver or burin is an instrument in constant use among artists in wood, there is no absurdity more grievous than to suppose the real merit or rank of an artist to consist in the kind of vehicle he uses. To this absurd pride many a suppressed invention is probably attributable. Engraving on copper was undervalued at the period of its discovery in Italy, till the persevering German mechanists invented the press. A kind of similar rivalry seems in this Country to have subsisted between painters in oil and in water colours, which has ended in a series of unforeseen triumphs for the latter.

† From λίθος, a stone, and γράφω, I inscribe.

‡ A stensil (anciently called pattern, or stanefile, see *Phil. Trans.* for 1709, No. 310. p. 2397.) is a thin plate of tin or other metal, and sometimes a piece of card or thick vellum, with holes in it cut to the shape of objects: so as that when it is laid over any print, the paper underneath the stensil receives from the brush of the operator a wash of colour through the perforated parts. Mr. Singer, in his *History of Playing Cards*, p. 179, quotes from Breitkopf the method practised by the briefmahlers. They pasted an impression of their print on pasteboard, and cut out all the parts which were to receive the same colour. For the whole work they accordingly required as many pieces of pasteboard, called *patrones*, (stensils,) as there were colours in the design. The colours thus laid on contributed to finish the picture and supplied frequently the form of many parts which were not expressed by the lines of the wood-cut. Probably some of our readers will recognise the similarity of this process to a method of drawing called *oriental tinting*, recently much in fashion and in which stensils are used.

A third variety of the mixed or compound class might be here introduced, namely a sort of chiaroscuro prints by the union of impressions alternately from wood and metal: first printed from a copper-plate and then shaded by wooden blocks; but as this implies a previous acquaintance with engraving or etching in metal, we include it under Chalcography.

The Engraver, like the painter, has certain pictorial elements to be carefully studied and pursued, and adhered to, whatever be the vehicle by which he works. Both artists must, it is obvious, begin their course together in the same school of drawing and of chiaroscuro. Both have the same necessity for perfect acquaintance with anatomy and perspective. Both are interested in expressing with truth and vigour, not the outlines only, but the surfaces and texture of bodies; as also the changes which light and air, in their innumerable modifications, unfold to the observer of Nature.[*] Engraving may not inaptly be called the translation of Painting into a language of which the phraseology is, in many instances, the same as the original; but which, in many more, retains, nevertheless, its own proper idiom: and of this idiom a good translator will always be able to avail himself. He never can arrive at such an end except by familiar acquaintance with his means; namely, with the peculiarities of the two languages in question. The work, to be properly translated from the canvass to the copper-plate, must undergo such idiomatic changes as belong to the employment of the new material. In every such work of taste, literal interpretation must not be mistaken for fidelity: otherwise a bald, and spiritless, and unsatisfactory result will be inevitable.

rinciples f Line ngraving.

(14.) The chief study of the Line Engraver, whether in wood or metal, is to contrive such an arrangement of his lines as will be most appropriate for marking the character of each particular object so as to distinguish it from every other, and preserve, at the same time, its proper keeping, (see PAINTING, p. 575. Art. 282, 283.) place, and value in the general composition of the picture. His lines for giving the greatest smoothness and polish are parallel; for extreme hardness and dulness cross each other perpendicularly; or for intermediate degrees take what is called the lozenge-form, and cross each other at some angle less than a right one. The latter have the name of lozenge-hatchings; the former are termed square-hatchings. For a flowing effect these parallels or hatchings will be more or less curved; and, on the other hand, to express stiffness or immobility, or some determined instantaneous action, they will be rectilinear. Again, where any object is to be distinctly prominent, (an effect which greater powers of contrast in the use of colours render variously attainable by the painter,) the Engraver, by giving the lines which shade the object a different direction, or a different degree of thickness, or a different interval between them from the lines which compose surrounding objects, may obtain the utmost force and perspicuity. When, on the contrary, this relief would be improper, and objects require to be flattened or brought nearer together in a position on the same plane almost equidistant from the spectator; here a general assimilation of the lines and shadings is resorted to.[†]

(15.) Another Work of Adam Bartsch, published at Vienna, 1821. in 2 vols. 8vo., entitled, *Anleitung zur Kupferstichkunde*, contains much useful and practical information on the arrangement of lines, technically termed *handling*. He observes, however, that a description of all the various ways adopted by judicious Engravers for the purposes of their Art, would, in words only, be a task impossible. We are entirely of the same opinion; and we therefore proceed, after the example, and upon the basis of so skilful an authority, to offer only some general remarks.

Handling considered in two ways.

First, we shall consider the most received and most successful methods of distinguishing each several kind of object from any other: and,

Secondly, how to do this so as not to interrupt the unity of the whole, but to contribute towards the harmony and combined effect of the engraved picture.

1. Distinct texture of various surfaces.

(16.) The sort of surface which it seems of most importance to remark upon, and which requires principally the notice of the Historical Engraver, is that of the human head, and the human skin or complexion. Next to this may be reckoned drapery; and lastly, other bodies, whether natural or artificial.

Of Flesh.

For the carnations and texture of the human skin, the half shadows (PAINTING, p. 580. Art. 290.) are expressed less frequently by lines or strokes than by dots. Sometimes these dotted marks are perfectly round, and consist of small conical holes made in the plate, with their apex downward, by a dry needle, punch, or etching point. (See plate i.) At other times they are angular, and each dot consists of a small isosceles triangle, made by a peck of the dotting graver. (*Ibid.*) If the peck be repeated in the same dot, as is the case in Chalk Engraving, the figure of the dot becomes a small irregular polygon.[*]

Some Engravers who use the burin only (Mr. Bartsch

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[*] The word colour is frequently applied to engraved works, and is, of course, applied in a somewhat different sense from that of the same word applied to Painting. No ideas of actual red, blue, and yellow, or of their compounds, can, of course, be presented to the spectator of a picture composed of only black and white. But we have already noticed on the subject of *Chiaroscuro*, (see PAINTING, last note to Art. 282.) that certain tints of red, blue, &c. have a certain value or keeping, a certain degree of prominency or of unobtrusiveness in every good pictorial composition. The business of the Engraver, and sometimes his chief difficulty, is to estimate exactly this value, and to represent it, as far as the representation is practicable, in black and white. Colour, too, is often only another term for the quantity of black pigment (Art. 7.) which the plate, by being well engraved, is capable of giving out upon paper.

[†] See Note (D.) at the end of ENGRAVING.

[*] The works of Luigi Schiavonetti, Anthony Cardon the younger, and John Hall, contain, perhaps, the best modern specimens of stippling judiciously united with the lines of the graver. In some of the Engravings of Schiavonetti, who was not only admirable in the chalk manner but also as a Line Engraver and with the burin, his stippling is wrought into lines such as, in drawing with a crayon, are usually hatched. A beautifully limpid effect is thus produced for water, and a clear, firm precision of character for earth, stone, &c. From the earliest stage of the Art the best line Engravers (under which term are comprehended those who only or chiefly use the burin) have always intermingled stippling with their lines: and examples of this practice continually present themselves among the many admirable Portrait Engravers of the French School. Since the invention of Chalk Engraving, either an admixture of lines with stippled work has been generally introduced, or the dots of the stippling have been arranged in courses to resemble lines in chalk. Such was the method of the masters mentioned at the beginning of this note. Wood Engravers, likewise, practise frequent stippling with the burin. The carnations of the female form, and of children, being peculiarly delicate, require in their half tints a greater number of dots and more stippling than the male figure. Sometimes the stippling takes the appearance of very short lines blunted at each extremity and carried along like links of a chain in a direction appropriate to the form of the object. Between these rows of short or stippled lines, and between the extremities of any two of them, small dots are often inserted as fine as it is possible to execute them, the better to blend the shadings, and give softness. In proportion as these stippled lines approach the light, the shorter and finer they become; until at length they dwindle insensibly into small round points. On the opposite or shady side of the figure they follow a quite opposite rule. They must, as they approach the strong shadow, be drawn to greater length; and must at last join their extremities and form but one continuous line in that part where a second class of strokes forming simple hatchings is added. In illustration of this Mr. Bartsch refers to many excellent examples in the works of Bartolozzi, of Sir Robert Strange, and of other modern artists.

quotes Edelinck and Wille as examples) produce their delicate gradations of shadow altogether by continuous lines, to which they give, according to circumstances, a greater or less degree of fineness. Next they introduce between these lines with a pointed instrument, or stylus, a number of minute punctures at equal intervals. "This process," he observes, "demands a very practised and clean graver; but it promises, if the lines are drawn with proper delicacy, to answer, effectually, the purpose."[*]

Of Hair.

(17.) Hair is best expressed by lines running in parallels, which in order to mark the shading must be swelled or strengthened to the depth required. The strokes for light hair must be of greater fineness, but must, nevertheless, be full of colour. They must in every case lie near together. In works of magnitude where detail is required, such as portraits, single hairs of a curl are left white, and others added in a mass, an expedient which produces an excellent effect.[†] Hatchings (Art. 16.) are seldom used for hair except in the broad masses of shade where partings of the hair are not discernible. The cross strokes, however, must always be more delicate than the lines over which they are laid. "A double crossing, or third course of lines is," says Mr. Bartsch, "quite inadmissible in representing hair, and should never be attempted.[‡]

Handling. Of drapery.

(18.) Drapery. Different kinds of drapery require very different handling. Velvet is very appropriately represented by a course of thick strokes full of colour, interlined with others finer and thinner. Where these lines approach the light they must be drawn to a point, and the intermediate strokes made somewhat shorter. In broad masses, requiring for the above arrangement of alternate thick and thin lines a stronger quantity of colour, the effect is produced by wide hatchings, the lines of which are swelled out or drawn finer according to circumstances. This second series of lines crosses the first without the accompaniment of any intermediate strokes.[*]

Of other substances.

(19.) Other substances. All hard and polished surfaces are represented by parallel lines (Art. 14.) clearly and sharply cut, which vary in thickness according to the degrees of light and shade. To give an effect of dazzling lights introduced abruptly on a dark shadow, (as is the case with polished metals and other shining bodies,) the shading lines should not in general terminate in an insensible point, but break off at once upon the bright reflection. Hatchings, except for the darkest shadows, are rarely used, and are most employed where some adjacent object takes off the shining effect. Let the second series of lines in these hatchings be always considerably finer than the first.[†]

Sky, clouds, smoke, ground, stones, and wood, are generally executed in the early process of the Engraving. In landscapes engraved on metal, the trees, rocks, earth, and herbage should be etched as much as possible. Nothing should be left for the graver but to perfect, soften, or strengthen the previous touches.[‡] Whenever objects of this kind are intended to come out distinctly,

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[*] In portraits, where the greatest accuracy must be preserved for delineation of the finer muscles, dots made with the graver have the best effect. Their somewhat lengthy form very much assists in expressing the pores of the skin. To produce in a portrait tones of complexion a little stronger, these dots are often placed more closely together: but oftener, and more successfully, the effect is obtained by a course of fine strokes between which in an oblique direction the dots may be introduced. Mr. Bartsch quotes the best works of the most eminent Engravers—portraits from the burins of J. G. Wille; the Drevets; G. F. Schmidt; G. Edelinck; and François Chereau; the last of whom he distinguishes for peculiar truth and delicacy in engraving the hands and extremities. Shadows of a deeper class are produced by two or three crossings of delicate strokes rather near each other. The powerful shadings which result from two crossings of thick strokes, full of colour, are unsuitable to the delicacy of the human complexion. They can be introduced only in very small heads, and in small portions of shadow; but in such a case the white squares, or lozenges, or interstices must be filled up with dots. In naked figures, these dots must be sparingly introduced, and used only in the weaker shadows, or half tints, consisting at most of two courses of lines. Some good old Engravers were in the opposite extreme, and were too sparing of dots. Their carnations, consequently, want softness. In the celebrated print of Judith, which Cornelius Galle the elder engraved after Rubens, and which is admired as a *chef-d'œuvre*, the absence of this charm is painfully evident, since in the figure of Holofernes, and in those of the Angels hovering over the tent, the carnations are executed by lines only, and with the same handling as the draperies. When these dots, which are chiefly employed for the human skin and complexion, occur betweeen lines, they are usually made equidistant from each other, and in the half shadows assume a longer form, taking a direction conformable to the shape of the body or muscle to be engraved, and more or less apart from each other according to circumstances. At the same time we must observe that an excessive and overwrought alternation of little short lines and of dots made with the graver, laboriously introduced in triangles or crosses, will produce a glassy effect, and diminish rather than promote the delicate softness proper for carnations. Mr. Bartsch instances this defect in Wille's Engraving of the death of M. Antony after P. Battoni: and also refers to the breast of Nessus, in an Engraving of Nessus and Deianira after Guido, the otherwise admirable *chef-d'œuvre* of Wille's pupil, C. C. Bervic. We admire, says he, the power of Art, but lament the absence of truth and nature. A beautiful example of soft carnation is given in the figure of Hymen engraved by Bartolozzi in his "Clytia" after Annibal Caracci. *Anleitung, &c.* vol. i. p. 85. sec. 256—260.

[†] Mr. Bartsch (*Anleitung, &c.* sec. 261.) instances among the best works of Antoine Masson portraits of W. Brisacier and of G. Charier.

[‡] *Ibid.* sec. 251. The portraits engraved by Jacob Houbraken exhibit beautiful specimens of hair delicately executed. Short hair and fur must uniformly be expressed by short and sharply pointed strokes, with more or less softness according to the sort of skin. In masses of shade, and particularly in the darker masses, an alternation of fine with somewhat deep (*stärkeren*) strokes judiciously combined will have a good effect. Cross-hatchings must be very rarely used in delineating fine white furwork, and must wherever it is possible be altogether avoided. Excellent representations of fur are to be found in portraits engraved by G. F. Schmidt; the Drevets; François Chereau; J. G. Wille; G. Edelinck; J. Muller, and C. C. Bervic. Mr. Bartsch particularly admires a beautiful dog in the portrait of young Frisius engraved by H. Goltz, and the "reposing Lion" of the elder James Gheyn. *Ibid.* sec. 262.

[*] See Note (E.) at the end of ENGRAVING.

[†] Fine specimens of shining metal occur in the "Observateur distrait" of Wille, and in the portrait of the Count S. Florentine, by the same Engraver, where a silver inkstand and gilt framework of a chair exhibit masterly handling. An Engraving, after Titian, by Michael Natalis, of the Marquis del Guest, is an admirable example of glittering armour. The disagreeable effect of hatchings used too freely, and of lines too strongly marked for representation of shining bodies, may be seen in an Engraving published by Wille, in A. D. 1743, consequently earlier than his best manner. It is a portrait of General Belle Isle, after H. Rigaud.

[‡] "From the shape of the burin," observes Mr. Gilpin, at p. 48. of his *Essay on Prints*, "each stroke in the copper is an angular incision, which form must, of course, give the line strength and firmness, if it be not very tender." Another operation, however, serves for finer and more delicate touches. It is performed by cutting into the copper with a steel point held like a pencil. This is called the *dry* point or *dry* needle, to distinguish it from the same kind of instrument used previously to the application of *aqua fortis* in etching. Incisions more or less deep by pressure of the dry point produce lines more or less chargeable with colour, but always feebler and more delicate than lines with the graver. The dry point, therefore, may be used with great advantage in fine linen, skies, distances, ice, and often in water, especially in small Engravings. In most things, it is proper to etch the shadows, leaving only the lighter tints for the dry point. See Note (B.) at the end of ENGRAVING.

prominently, or in great masses, they must be worked up separately, and with a variety of handling.[*]

(20.) The representation of soft earth is made in the lights by detached strokes; in the shadows by continuous ones; but always by such as are waving and irregular. At their termination they break off abruptly. In darker shadows, "we generally use," says Mr. Bartsch, "two or three series of hatchings, the strokes of which, like those of the foundation over which they cross, must be crooked; must be somewhat angular; must be here and there broken or discontinued; and must have abrupt endings."[†]

2. General effect.

(21.) Thus far we have selected for observation a few of the peculiar methods of handling by which each kind of object separately considered may be distinguished from the rest. We will now proceed to take some brief notice of what was secondly proposed (Art. 15.) respecting pictorial effect. The same authority whom we have thus far chiefly followed, observes, that in order to form or pass a fair judgment in this respect upon an engraved picture, it is of much greater moment to examine the *direction* of the lines and hatchings (*conduite des hacheures*) than to examine whether they have been chosen according to received rules of mechanical execution. The choice of strokes for Engraving resembles the selection of colours for Painting. The proper colours may be well known and fixed upon. But a further process much more important is to come. They have yet to be duly mixed and blended on the pallette, and laid on with a judicious pencil. To this process Mr. Bartsch compares the direction of lines and hatchings in an Engraving. "For the first of the above purposes," says he, "in both Arts (*viz.* for choice of lines and colours) moderate talents and but little experience are necessary. But for the second, there must exist great genius, much reflexion, and constant practice."

The author then goes on to recommend a careful study of the best Engravings, and maintains the impossibility of giving more than very general written instructions. All courses of lines, especially that (whatever afterwards be the number of hatchings) which composes the first series or foundation, must take a direction inclining to the form of the body to be represented.[*]

Keeping.

(22.) The degree of force or delicacy in handling must be chiefly regulated by the size of the plate. The paramount object of an Engraver is to produce his shadows in such a manner that they shall preserve their proper keeping in the picture, and appear as if spread with a brush, although really executed by the juxtaposition of lines. As the artist's aim, however, is not only to represent shadows, but also the various texture and character of the substances shaded, (Art. 16—20.) his execution must avoid the extremes of excessive strength and excessive fineness, and must always be in perfect keeping also with the size of his performance. If the handling is too fine in a large object, which in order to be viewed as a whole must be viewed at some distance from the eye; then the texture of the substance or stuff will be indistinct, and its larger shadows will lose their power. On the other hand, if the execution be too coarse in a small representation, which in order to be seen in detail must be seen much closer to the eye, the effect of such a work will be spotty, will confuse the spectator, make the smaller portions of the representation indistinct, and on the whole be disagreeable.[†]

The above rules belong to all three branches of Engraving.

(23.) Our readers will have perceived that the foregoing principles of Line Engraving, although perhaps especially intended for works on metal, are equally applicable to Line Engraving in wood, or to Lithography. But they apply principally to finished and elaborate chefs-d'œuvre. For mere sketchy performances no precise rules can or need be given. Of such it is enough to say, that the more nearly they produce the imitation of a slight drawing or sketch the greater their merit. It will be seen, however, that other styles of the Art exist, such as on plates of metal, the mezzotinto, and the style of Le Blon; or in wood, the style called printing in chiaroscuro; each of which, in skilful hands, is capable of great force and beauty, but for none of

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[*] To the late Mr. Wilson Lowry, F.R.S. the Art is indebted for an admirable invention called the "ruling machine." It is an apparatus for engraving any series of parallel lines, either all equidistant, or having different intervals between them in just gradation from the greatest required width to the nearest possible approximation. It wonderfully economizes labour, and gives a facility before unknown in all subjects for which a smooth, flat tint is required; such as the blue part of a sky, still water, &c. But it is more especially useful in plates of machinery, &c. having reference to scientific illustration. Many engraved works, and particularly those for the Cyclopædias, bear testimony ever since this invention to its unequalled accuracy and beauty of execution. A diamond point (the use of which for etching was first introduced by Mr. Lowry) is connected with the ruling apparatus, and passed over the copper, so as to make the required incision through the etching ground. (See plate i.)

Clear blue sky should be represented by very fine horizontal parallels perfectly straight and cleanly cut, always made more delicate and occasionally somewhat wider from each other as they approach the horizon. Hatchings are not allowable, unless in a space surrounded by clouds; but even then they give a grey and sombre effect rather than of pure azure. Clouds are imitated by a series of strokes delicately drawn, running closely together, and always so contrived as to follow the shape of the cloud. In sunshine, and for very white clouds, a single course of very delicate strokes is sufficient; but should even those produce a tone too powerful, then small detached strokes which must, however, fall regularly into rows, may be substituted. Darker clouds admit of two or three series of cross lines. In the darkest parts, these hatchings are only strengthened; but the adaptation of his lines to the form of the cloud is the Engraver's chief aim. Where they approach its outline, each class, or course, or series of lines, must always be shorter than the preceding. The lines also of one portion must so blend with those of another that although a distinct separation is somewhat effected by the shading, yet, like all vapours, they may appear to hang one from the other. Clouds formed by smoke and vapour are handled similarly to atmospheric clouds. An excellent example of clouds of smoke is given in Woollett's Engraving after West's "Battle of La Hogue." Clouds of dust do not hang together so much as others. The series, therefore, for shading them must consist of shorter, and rather broken lines.

[†] See Bartsch, *Anleitung*, &c. vol. i. sec. 275. p. 92. Also see Note (F.) at the end of ENGRAVING.

[*] See Note (G.) at the end of ENGRAVING.

[†] It follows that the Engraver can never venture to exceed figures of a certain size without prejudicing the beauty of his work. A judicious artist will never attempt by lines and dots to represent a human head the size of life. Nanteuil and Masson have made the trial, but have had no imitators. The gigantic heads sometimes engraved by these justly celebrated artists excite admiration rather for expert use of the burin, than for general effect in each composition taken as a whole. Where powerful shadings are required in enormous objects, like the heads in question, the strokes for that purpose must either be too strong and too deeply charged with colour, (*genährtere*, literally *fat*,) or must be too frequently crossed. In the former case the work betrays coarseness: in the latter it has a cramped and scratchy effect, very disagreeable, especially for representing flesh. The figures of Christ and the Virgin in two sheets by Louis Cossin after Le Brun may serve as examples of figures far too large for the graver. See Bartsch's *Anleitung*, &c. vol. i. sec. 291. p. 99.

which (as they do not depend for effect upon the arrangement of lines) the preceding observations can, strictly speaking, be available. To become an adept in these latter styles of Art, considerable experience in the practice of Painting seems indispensable, not only as regards the province of the crayon, but of the brush, not only in the composition of light and shade and monochroms, but also in the actual use of colours. Successful attempts have been comparatively few ; and it is probably to deficiency in the requisite pictorial knowledge that so many failures ought to be attributed.

Usefulness of this Art.

Having now, by a kind of elementary introduction, prepared the way, as we think, for an enumeration of the most remarkable competitors who have successfully aspired to fame in the several branches of Engraving; we shall not detain the reader with remarks on the importance of the Art itself, but conclude him to be already satisfied of its universal utility; its aptitude for scientific illustration; its essential and vital services to experimental Science in diffusing the comforts of civilized life; its value to Literature, and above all to true Religion in preserving and strengthening, by the spread of local knowledge, the foundations of historical truth; and finally its power to delight as well as instruct mankind, by multiplying and giving almost ubiquity to the most precious gems of every Cabinet; the rarest natural wonders of every Museum; and the finest efforts of the human imagination whether in Painting or in Sculpture, of every School, every collection, every Gallery that exists, or that has existed since the XIVth Century.

Xylography. Its origin Oriental.

(24.) Wood Engraving, as being the earliest of the different kinds mentioned for taking impressions, (Art. 12.) stands first in the chronological order, which, in the subsequent pages, as far as is conveniently practicable, we shall pursue. The Oriental origin of wooden tablets for preserving public records is indisputable.* But on the question how soon the process began of printing from blocks, or wooden tablets, antiquity has hitherto been silent.

Probably brought to Europe from China.

The learned Baron Meerman, in his *Origines Typographicæ*, quotes, from a History of China written by Abusaid in Persian, A. D. 1317, the following passage among others to show that the Chinese of that period had long been familiar with the Art. "All the books edited by the persons in question (alluding to three Chinese sçavans whom he names) are written in a beautiful hand, so that each page may be transferred in the same handsome character to the blocks, with which the men of learning are always at great pains to collate their MSS. attesting by a private mark on the back of each block their approbation of it. They next commit these blocks or tables to the best Engravers, and finally complete the whole work by numbering the pages." The Persian writer next describes the care with which these tables (somewhat similar in form, perhaps, to our plates of stereotype) were preserved in cases under the seal of conservators incorporated as a college for the purpose, to whom all applications, when a copy was required, were to be made; and on the payment to whom of a stated fee, the copy upon paper, with the seal of the proper functionary attached to it, warranting its genuineness, was granted.† Such a system, so methodically organized, argues, certainly, long previous custom. The Baron Meerman is unwilling to go back with some writers of doubtful authority, to a date preceding the Christian era, but agrees with the able and accurate Couplet, a Jesuit Missionary in A. D. 1659, and a resident for several years in China, that the date of A. D. 930 may be fairly assigned for Chinese impressions from wood.*

(25.) Facts like these, joined to the much freer European intercourse with that extraordinary people nine hundred years since than exists at present, supply a very sufficient reason, as Mr. Ottley has well observed, why Marco Polo, in his account of China, written after his return to Venice in the year 1295, should have made no mention of Wood Engraving among the marvels of that Country. Had the Art been unknown at Venice, the Venetian traveller could not have omitted the communication to his Countrymen of what in China must have met him at every turn, and what to his genius and acuteness could not but have appeared a most felicitous, most strikingly useful, and marvellous invention. We concur, therefore, in the belief, that a communication such as this would, in the days of Marco Polo, have been "old news" at Venice, and therefore could find no place among his *marvels*.‡ The merchants and nobles of Venice had maintained almost exclusively an uninterrupted commercial intercourse for two centuries before with the East, as well through Alexandria and Cairo as through Constantinople; of which latter illustrious city they had, in the year 1203, been masters, and in which, ever since the year 1084, their factories had been regularly established under the especial sanction of the Greek Emperor.§

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* See Note (H.) at the end of ENGRAVING.

† Meermanni *Origo et prima Specimina Impress. tabellaris*, cap. ix. sec. 2. Also see Note (I.) at the end of ENGRAVING.

* *Præ ceteris probabilis videtur exactissimi scriptoris Phil. Coupletti opinio*, A. D. 930 *assignantis. V. in Chronologiâ Sinensi, annexa Confucii operibus*, p. 65, *ubi impropriè eam (artem scil. apud Sinenses) typographiam vocat. Hic vero auctor quam longissimum tempus in Chinâ transegerit, atque accuratam rerum ad hoc regnum pertinentium notitiam acquisiverit, ex optimis sine dubio fontibus id hausit.* V. Meermanni *Origines Typographicæ, ad* cap ix. sec 1. in note.

† The Chinese, observes Macpherson, were more commercial and enterprising in the IXth than in the XVIIIth Century, vol. i. p. 281. Asserius, the great biographer of the great Alfred, mentions his having seen a correspondence of that Monarch with the Patriarch of Jerusalem, which probably suggested to Alfred the benevolent but adventurous design of sending relief to the Christians of St. Thomas in India. Sighelm, Bishop of Sherburne, (to which See Asserius was afterwards translated,) was the person sent, (as William of Malmsbury informs us,) with many presents, on this expedition, and accomplished it prosperously. To the wonder of his Countrymen, he penetrated even to India, bringing thence aromatic liquors or oils, and splendid jewels, some of which remained in the treasury of the Church, when the author wrote. Mr. Macpherson (*Annals of Commerce*, vol. i. p. 263.) very feelingly laments over these meagre records, all that remain to us of this important transaction. The Saxon Chronicle and Radulf de Diceto repeat the history, but are still more uncircumstantial. He observes, that "the early writers could have no motive, if they even possessed capacity, for inventing such a narrative, though it may not be true to the fullest extent. Sighelm went from England to Rome in the year 833, and probably got a passage from some of the Italian ports to Alexandria or Phenicia. It is not impossible (though very difficult for a Christian) that he may have made his way to the South coast of Arabia, or to Bassora, and have proceeded even to India. But if he purchased Oriental commodities in Alexandria, Arabia, or Bassora, any of these places would be confounded with India by his Countrymen, who were ignorant of the geography of Countries much nearer to them." We are inclined, however, to believe, that in the stirring times of King Alfred, the perils of this Indian journey would be less thought of than the length of it: and that a fuller account of it would have been recorded, had the obstacles been such as it was unusual for Oriental Christians, or pilgrims from Italy, to surmount.

‡ See Note (K.) at the end of ENGRAVING.

§ The Venetians obtained this privilege in return for the protec-

But the dawn was now arrived of a new day for civilization in Christendom. The Venetians after deriving from their Oriental commerce so many useful and profitable Arts had not the power, even if they harboured the intention,* of confining them to their own Country. To whatever ports of Western or Northern Europe their fleets were bound, and to whatever inland cities the intercourse with Italy (which during that reign of Popery must have been frequent†) extended, the acquaintance with Asiatic customs, and manufactures, and inventions, would be more or less gradually advancing. Genoa, also, and the other rivals of Venice would assist, unknowingly, it is true, but not less effectually, in this inevitable dispersion of the seeds of useful knowledge. And accordingly we find that, almost by a simultaneous impulse, in or near the great commercial marts of the North, especially in Germany and the Low Countries,‡ the Art of Printing from blocks appears coeval with the same practice in Italy. The Germans, whose skill in mechanism was proverbial in the XIVth Century,* were probably the inventors of the printing press, which succeeded to the ancient method practised to this day by the Chinese, namely, the application of a brush or hand-roller to the back of the paper, after laying it, in a dry state, on the block ready charged with ink for the impression. The invention also of printer's ink, suggested probably by the discovery of oil painting, gave to the early German prints a great mechanical advantage over the first essays of Italy.†

Ancient Xylography.

(26.) It has been usual to give the name of "old masters" to such Engravers, whether in wood or metal, as practised the Art from its introduction into Europe to the end of the XVIth Century: and to divide these into only two Schools, that of Italy and that of Germany: in consequence of the comparatively very few old Engravers to be found in other Countries, and the style of those few being traceable to one or other of the two sources mentioned.‡ We propose to adopt the latter mode of division with respect generally to the two Schools of ancient Engraving: but, at the same time, with respect to the present branch of the Art, or Xylography, we consider it most convenient to include under the old Schools artists also of the XVIIth Century; so as to date modern Wood Engraving from the times of Papillon and Count Zanetti, near the commencement of the XVIIIth.

Only two ancient Schools: the Italian and the German.

(27.) To begin then with the old Engravers on wood, according to the simple process, and in the School of Italy.§

Old School of Italy.

Alessandro Alberico Cunio and his twin sister *Isabella*, born about A. D. 1270, are recorded as the earliest practitioners in this Art whose names are known. Their interesting history is given by Mr. Ottley, as compiled from the Works of Papillon, who saw a set of their Engravings, eight in number, and wrote down at the time a particular description of each, together with various memoranda respecting them out of the Work itself, originally written in the Swiss language, but translated to him by M. de Greder the possessor. These young persons passed their youth in the cultivation of their highly-gifted minds, and when arrived at the age of sixteen, had perfected themselves in various accomplishments, among which the Arts of Design and Engraving on wood were conspicuous. It is not improbable that they acquired their artistic knowledge from some monkish illuminist, or *formschneider* in the Religious houses of that period, with whom they might form accidental acquaintance through the circumstances attending the clandestine marriage of their noble parents. For their own amusement and the gratification of their friends, Alessandro and Isabella composed and jointly executed a series of prints representing the "heroic actions of Alexander the Great," with an appropriate dedication

Simple process in wood. The Cunio.

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tion afforded by their fleet against the incursions of the formidable Norman pirate, Robert Guiscard, with whom they disputed the command of the Adriatic. Through Constantinople their facilities of trading Eastward to the utmost boundaries of Asia were obvious. The Mogul Empire, or Empire of Tchinghiz Khan, extended, A. D. 1226, from the Caspian to the Yellow Sea, and between 35° and 55° North latitude. In A. D. 1290 it reached from the borders of Asia Minor Eastward to the Persian Gulf, and thence to 65° East longitude. V. Klaproth, *Tableaux Historiques*. We think it probable that printed silks and calicoes preceded impressions upon paper. See Macpherson's *Annals of Commerce*, vol. i. p. 138, *et seq.* Before the invention of paper in Upper Egypt, whether at Memphis or at Seide it matters not, linen or cotton cloths were used for MSS. The Ancients, till the diffusion of that invaluable manufacture, the papyrus, seem to have tried every substance within their reach: palm-tree leaves, table-books of wax, ivory, and lead; intestines of different animals, and sometimes the backs of tortoises. There are few plants that have not at some time furnished materials or leaves for books. Hence the several terms biblos, codex, liber, folium, tabula, &c. expressing the different parts used for inscription. Hansard, *Typographia*, p. 202. See also note at p. 7. vol. i. of Bishop Tomline's *Elements of Christian Theology*.

[*] Temanza, a Venetian architect, had the good fortune to discover among the archives of the old Company of Venetian Painters (v. *Lettere Pittoriche*, tom. v. p. 320) a decree of the Government of Venice, dated 4th October, 1441, which throws much light on the subject of early block-printing, and which the reader will find quoted at length in Ottley's *Hist. of Engraving*, p. 47, and in Singer's *Hist. of Playing Cards*. The trade of the native artists in Venice had fallen, as appears from the preamble of this document, into decay, (in consequence, we presume, of a considerable influx of similar goods from the foreign market,) and the decree was passed to exact a protecting duty upon all imported work of the "art or mystery of making cards or painted figures, whether printed or painted on cloth or paper, altar pieces, (*ancone*, perhaps a corruption from *εἰκὼν*, *icon*, an image,) playing cards, (*carte da zugare*,) or whatever work of said Art is done with a brush and printed." "The most reasonable conclusion," says Mr. Ottley, commenting on this and other circumstances respecting the revival of Arts in Europe, "is, that the Venetians acquired the Art of Wood Engraving at a very early period of their intercourse with the people of Tartary, Thibet, and China, that they practised it among the other Arts which they had learned from their Eastern friends, as a mean of beneficial traffic with the Continent of Europe; and that in course of time the artists of Germany and other parts found out their secret, and practised it themselves." See *Hist. of Engraving*, p. 59, 60, and Zani, *Materiali*, &c. p. 77.

[†] The Italian merchants dispersed throughout Europe became very convenient agents for the Popes, who employed them to receive and remit the large revenues they drew from every Country which acknowledged their Ecclesiastical supremacy. It seems probable that they also employed them to lend their money upon interest, whence they are called the Pope's merchants, as Matthew Paris (p. 419. 423. &c.) expresses it. Macpherson, *Annals of Commerce*, vol. i. p. 399.

[‡] See Note (L.) at the end of ENGRAVING.

[*] Manuel, the unhappy Emperor, was driven from Constantinople, by the terror of the Turkish arms, to mendicate assistance from the Christian States of Europe, among the descendants, says Mr. Macpherson, of those *barbarians* who had usurped his Western Provinces. The observations (towards A. D. 1400) of Manuel or his Greek attendants respecting the different places and Countries named in his tour, as Germany, France, Flanders, England. London, and Venice, are circumstantial and characteristic. Of the Germans, the Imperial traveller observes, that they *excel in the mechanic Arts*, and boast of the invention of gunpowder and cannons. *Annals of Commerce*, vol. i. p. 611.

[†] See Note (M.) at the end of ENGRAVING.

[‡] See the Preface to vol. vi. of Bartsch's *Peintre Graveur*, 8vo. Vienna, 1808.

[§] For the tools and materials in Xylography, see what follows in Art. 32.

in the frontispiece to Pope Honorius IV.,* to whom their mother, a noble Veronese lady, was related.

In our preceding columns (see PAINTING, p. 470.) we have already adverted to these times, the times of Cimabue and of his pupil and protégé Giotto; the former born of noble Florentine lineage, A. D. 1240, the latter born 1276, the son of a shepherd near Florence, whom his future patron and instructor discovered chalking the figure of a lamb upon a stone in his native fields. It was to such men as these, the contemporaries of the Cunio and of Dante, (born in 1265, about five years later than the Cunio,) that Italy owed the recovery of her intellectual refinement in Literature and in the Arts.† No authenticated prints, however, are extant to fill up a chasm here of more than a century and a half. But it is not therefore to be imagined that the XIVth Century in Italy was unemployed in works of Art, though probably less in Italy with regard to the Xylographic branch of it than in those other Countries of Europe which competed with the Italians so successfully as to bring Wood Engraving into decay among them, at least among the Venetians, according to the acknowledgment of a [illegible] of Venice A. D. 1441. We refer then to our short account of the *Quattrocentisti*, (PAINTING, p. 471.) with which the reader will fill up this interval, and we proceed to the next name among early Italian contributors.

Mocetus.

Girolamo Mocetto, or Hieronymus Mocetus, born about 1454 at Verona, was taught Painting by Giovanni Bellini, whose brother Gentile we have mentioned at p. 471 on PAINTING, as doing honour to Venice. Mocetto is said to have executed a wooden cut of the "Entry of Christ into Jerusalem," dated 1500.

Il Titiano and his brother Cesare Vecelli. Domenico Campagnola. Vicentino.

A fellow pupil of Mocetto, the great [illegible], is next on record as having, in 1505, when at [illegible] of twenty-eight, obtained high praise for a print of the "Marriage of St. Catharine." Other works are ascribed to him by Papillon. *Cesare Vecelli*, the brother, *Domenico Campagnola*, the best early scholar of Titian, and *Boldini* of Vicenza, or Vicentino, also Titian's reputed pupil, were Wood Engravers. The long life of Titian (ninety-nine years) must have enabled him to foresee, with no small gratification, how widely the Engraver's Art was to extend and perpetuate the fame of Painters.

Vico.

Æenea Vico, born at Parma in 1512, was at Florence in 1545, where he presented the Emperor Charles V. with the portrait which he had engraved of that Monarch, and for which, according to Gori, he received 100 crowns. It is a wooden cut surrounded by emblematical figures composed with taste and well drawn. It is executed with great care, and the hatchings in imitation of strokes are so well expressed, that Strutt, who saw this specimen, "can hardly suppose it to have been his first attempt." This learned person retired about 1568 to Ferrara, where he passed the remainder of his life under the protection of Alphonso II.

Ancient Xylography. Porro.

Girolamo Porro, born about 1520 at Padua, wrought at Venice, where his last performance was a set of wooden cuts for the *Funerali degli Antichi* of Tommaso Partacchi, published in 1591.

Guiseppe Porta.

Meanwhile, Florence, Bologna, and Rome added further specimens of Italian Xylography. *Guiseppe Porta*, a pupil, at Rome, of the Florentine painter Salviati, and himself an eminent painter, engraved on wood with admirable expression and effect. Bologna produced from the hand of the elder Coriolano, besides various other works, several very masterly performances in wood, after the designs of Vasari, for his *Lives of the Painters*, [illegible] published in 1568. This artist, a native of Nuremberg, who changed his name, as Heineken informs us, from Christopher Lederer to *Cristoforo Coriolano*, (alleging his descent from the Patrician so called,) seems to have striven hard for a place in the rolls of Roman fame. His son *Bartolomeo*, born at Bologna, also pursued the Art.

Coriolano, father and son.

Veronica Fontana.

Veronica Fontana, instructed in drawing by her father, and by the celebrated Bolognese painter, Elizabeth Sirani, executed small portraits in wood with great neatness.

Scaminosi.

Raffaelli Scaminosi too, the Bolognese painter, who flourished about 1610, performed some few Engravings on wood.

Family of Parasole.

Leonardo Norsini, (called *Parasole*,) a native of Rome, with his wife *Isabella*, and their [illegible] *Bernardino*, also were Wood Engravers. Leonardo, who flourished in 1600, was of some celebrity and much employed by Antonio Tempesta. At the command of Pope Sixtus V. he engraved on wood the plants, &c. for [illegible] herbal published by Castor Durante, physician to his Holiness. Bernardino was a painter as well as Wood Engraver. Isabella, his mother, executed in block printing several ingenious designs for lacework; and a considerable number of plants for the herbal of Prince Cesi. Another lady, *Hieronyme*, of the same surname and family, engraved after A. Tempesta, with much spirit but, with very incorrect drawing, says Strutt, and in a coarse style.

Juan Vingles of Zaragoza.

One example, the only one we have been able to record of a Spanish Wood Engraver may here be mentioned, *Juan Vingles*, who flourished at Zaragoza in 1550, and engraved in wood the illustrations for [illegible] *Ortografia Pratica* of Juan de Iciar, published there in that year. Bermudez, in his *Diccionario dellas Bellas Artes*, pronounces the cuts of Juan Vingles to be in good taste, with figures highly characteristic, and correctly drawn.

Compound Xylography of Italian stencilled prints.

(28.) Next, we are to name the ancient Italian artists who have used the compound process (see Art. 12.) of engraving in wood.

Of the first kind of compound process (for which stensilling* was introduced) few or no positively Italian specimens remain of which we are aware; though, doubtless, they must have been as numerous in Italy as in other parts of Papal Christendom, being especially employed for purposes of Religious worship† or instruction, or, to speak more plainly, for extending the influence of legendary superstition. The Abbé Lanzi saw in the Cabinet of the Count Durazzo, some ancient playing cards, from designs, as he conjectures, of Jacobello del Fiore. These were coloured in stensil. *Il lavoro*, says he, *a' periti è paruto a stampa i colori dati per*

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* See Note (N.) at the end of ENGRAVING.

† Giotto painted the portrait of Dante, who has thus celebrated him in the *Divina Commedia*.

Credette Cimabue nella pintura
Tener lo campo: ed ora ha Giotto il grido,
Si che la fama di colui è oscura.
Del Purgatorio, can. 11. l. 94.

The Poet here evidently alludes to the inscription on the tomb of Cimabue in the Duomo at Florence.

Credidit ut Cimabos picturæ castra tenere
Certè sic tenuit; nunc tenet astra poli.

It is remarkable that Ravenna, the retreat of the Cunio, was the last retreat of Dante. He died there under the roof of his hospitable patron, the Lord of Ravenna, soon after returning from a mission to Venice, in 1321.

* For an explanation of stensilling, see last note to Art. 12.

† See Note (O.) at the end of ENGRAVING.

traforo: and adds, *monumento piu antico non so in tal genere. Storia pittorica*, vol. i. p. 129.[*]

2. Prints from two or more blocks.

In the second class of compound Xylography, the Italians, with whom the invention of chiaroscuro[†] printing by successive impressions *from wood only* seems to have originated, are remarkable. The invention is attributed to

Da Carpi.

Ugo da Carpi, (born at Rome in 1486,) the fellow student of Raffaelle d'Urbino. His prints, though very slight, says Strutt, are masterly and spirited, and preserve at least a bold, striking resemblance to the sketches of the great painters (chiefly Raffaelle and Parmegiano) from whose designs they are taken. One block is used for the outline and darkest shadows, another for the lighter shadows, and a third for the demitints.[‡]

Domenico Beccafumi.

Contemporary with Da Carpi was another Painter and Engraver, *Domenico Micarino*, born of humble parentage, at a village near Sienna, who assumed the name *Beccafumi* of his patron in that city; where his paintings both in oil and fresco, and other works, (see PAINTING, p. 477.) procured him great reputation. He, too, had studied at Rome the master lines of Raffaelle and M. Angelo. He executed his chiaroscuro sometimes on two, sometimes on three blocks; one for the outline and deep shadows, the other for the lighter tints. He wrought after his own designs, as well as from those of Titian and others. But the process was in the hands of a much more distinguished Siennese artist of the same period,

Peruzzi.

Baldazzare Peruzzi; (PAINTING, *ibid.*) if a print attributed to him be his, representing "Avarice driven by Hercules from before Apollo, Minerva, and the Muses." "It is," says Strutt, "in three blocks; the first for the outline, the second for the deep shadows, and the last for the lighter tints; and is executed in a fine, spirited, bold style."[*]

G. N. Vicentino.

Guiseppe Nicola Rossigliani, called *Vicentino*, from being born (in 1510) at Vicenza, engraved also with three blocks, (the first for outline, the next for the more powerful shadows, the third for lighter tint,) after Raffaelle and other masters.

Parmegiano.

It was from Parma, however, that the genius arose, which probably brought this method of Engraving to all the perfection it attained in that Age. *Francesco Mazzuoli*, or *Parmegiano*, superintended, as is well known, the execution of many of his own designs, by Ugo da Carpi, Antonio da Trento, Andrea Andreani, and others. He was a profound master of chiaroscuro, in the best of all schools, that of Correggio, and would, no doubt, be careful to enforce the principles which his paintings prove him to have practised.

Antonio da Trento.

Antonio da Trento was his pupil, though five years older, being born (at Trent) in 15[illegible], and devoted himself by the recommendation of his master to Wood Engraving, for which he generally used three blocks; the first for the outline, the next for the dark shadows, and the last for demitint. These cuts are justly esteemed.

Andrea Andreani.

Andrea Andreani, born at Mantua in 1540, was of small celebrity as a painter, but the prints in chiaroscuro extant under his name are numerous and excellent. He settled at Rome, and frequently practised the disingenuous artifice (unworthy of his great talents) of effacing the names of other artists from as many blocks of value as he could procure, substituting his own cipher, and selling the prints for performances of himself. "At times," says Strutt, "he used only two blocks, (namely, for his slighter works,) but oftener three, and never exceeded that number; one for the outline and very dark shadows, the other two for two different tints." He carried manual execution to greater perfection than any of his predecessors, so that we find his prints distinguished by an unusually clear and determined outline.

B. and G. B. Coriolano.

Bartolomeo and *Giovanni Batista*, sons of Cristoforo Coriolano, already mentioned, (Art. 27.) have left respectable proofs of merit. Bartolomeo was an able designer. He confined himself usually to two blocks, one for his outline and dark shadows, which he performed like hatchings with a pen; the other for demitint. His prints show great judgment, and have a very fine effect.

Falcini.

Domenico Falcini, born about 1580, is another artist who flourished in the beginning of the XVIIth Century. His engravings (after Raffaelle) are performed by three separate blocks, one for outline, another for demitint, and the third for dark shadows.

Germany. Old Xylographic School.

(29.) The German School of Wood Engravers exhibits a far greater number of early specimens than the Italian.[*] We have above seen (Art. 28.) the branch of Xylography chiefly practised in Italy arrive to great excellence under the fostering eye of some distinguished Painters. In the German School a similar effect was produced at an early stage of what we have called the simple process of Xylography.

Wolgemuth and Pleydenwurff.

Michael Wolgemuth and *Wilhelm Pleydenwurff*, two artists of Nuremburg, contributed their drawings for the embellishment of Hartmann Schedel's publication called the *Nuremburg Chronicle*, in A. D. 1493. These efforts for improvement were ably seconded by the great patriarch of German artists,

Durer.

Albert Durer, the pupil of Wolgemuth, and a native likewise of Nuremburg. (See PAINTING, p. 485.) In short, Engraving was expected to do as much for Painters, as letter-press could for authors.

Invention of types suggested by Xylography.

The invention of Printing by movable types, (*typi mobiles,*) or the substitution of them for engraved blocks, (*typi fixi,*) whether by John Gutenburg, as has been thought most probable, or by John Fust of Mentz, or by Laurence Zaussen Coster of Haerlem, is incidentally connected with our present subject, but would detain us longer than our limits allow. It is a sufficient honour to the Xylographic Art to have suggested the invention. No disputer that we know of has ever questioned that from block books with engraved figures and scrolls, such as the *Biblia Pauperum*,[†] the *Book of Canticles*, *Ars Moriendi*, and *Ars Memorandi*, the *Speculum Humanæ Salvationis*,[‡] the *History and Visions of St. John*,[§] or Dr. Hartleib's *Book of Chiromancy*,[||] the idea of a

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[*] In Mr Ottley's "Examples of ancient masters," some remarkable fac similes are given of a set of playing cards *à la trappola*.

[†] See Note (P.) at the end of ENGRAVING.

[‡] *Il imagina de faire des camaïeux à trois et quatre planches, ou rentrées de teintes par dégradation dans la même couleur, et sans aucune taille; ce qui faisoit des mates* (flat washes) *de couleurs adoucies qui paroissoient avoir été faites avec le pinceau, et même il les imprimoit sur un papier gris, de sorte que les parties éclairées qui restoient du fond du papier faisoient une dernière teinte très foible, qui s'unissoit parfaitement bien avec celles des planches gravées et toutes ensemble elles imitoient fort bien la peinture en camaïeu. C'est là l'invention qu'on doit rapporter à Ugo mais non pas l'origine de la Gravure en Camaïeu qu'il n'a fait que perfectionner.* Papillon, *Traité, &c.* tom. i. p. 392, 393.

[*] See Note (Q.) at the end of ENGRAVING.

[†] See Note (R.) *Ibid.*

[‡] See Note (S.) *Ibid.*

[§] This and the others, with the exception of three, *viz.* the *Biblia Pauperum*, the *Canticles*, and the *Speculum Humanæ Salvationis*, Mr. Ottley conceives were probably the rude manufacture of the ordinary cardmakers.

[||] The name of Jorg Schapff, the person who, according to more convenient method for types, first perhaps for whole words, and at length for letters, arose.

Eight remarkable cities.

The cities of most celebrity in which Xylography, according to the ancient German School, was practised in its simplest form, were Nuremberg, Augsburg, Antwerp, Strasburg, Amsterdam, and Leyden, to which we may add Lyons and Paris.

1. *Nuremberg.*

Nuremberg, for a length of time, preserved the character which the genius of Albert Durer and his people obtained for that City in the Arts. We have mentioned works of Pleydenwurff and Wolgemuth. From those of the indefatigable Durer, Mr. Ottley, improving upon the Catalogue of Bartsch, gives a description of 145 subjects.* Among them is the "Apocalypse of St. John the Evangelist, a set of sixteen pieces with explanatory text, (of this the first edition was printed in 1498,) also the "Fall of Man and his Redemption through Christ," a set of twenty-seven pieces, out of which Mr. Ottley presents his reader with four impressions beautifully printed from the original blocks, in the possession of Mr. P. E. Boissier. Another set, consisting of twenty pieces, represents the "Life of the Madonna."† *Hans Schauffelein* the younger, and *Hans Sebald Beham*, native of Nuremberg, followed in the steps of Durer.

Hans Schauffelein. H. S. Beham.

From the works of the former Mr. Bartsch describes 132 subjects, but doubts whether Schauffelein engraved any of them, though they bear his mark.‡ One of them is a set of twenty-two pieces, for a Work entitled *Himmelwagen und Höllewagen*, by Hans von Lenrodt, published at Augsburg, in 1517. Another is of forty pieces, for *Der Teutsch Cicero*, by Heinrich Steyner, Augsburg, 1534. Another, of seventy-three pieces, explained the Doctrines, Miracles, Life, and Passion of Christ, 4to., Frankfort, 1537. Of Beham Mr. Bartsch enumerates 171 subjects, of which seventy-three cuts belong to Scripture History, a set of eight for the Passion of Christ, and a set of twenty-eight for the Apocalypse of St. John. The first publication of Beham's *Biblicæ Historiæ* was at Frankfort, in 1536.

H. Lautensach.

Henry Lautensach, who followed the style of Sebald Beham, is said to have also engraved in wood. Two subjects, with the mark of his son, Hans Sebald Lautensach, are mentioned by Bartsch. He died at Nuremberg in 1590.

Virgil Solis. J. Amman.

Virgil Solis, who was born in 1514, at Nuremberg, and Jodocus or *Justus Amman*, who died there in 1591, are well worthy of mention. The works of Virgil Solis on wood, (for several of which see Bartsch, *Peintre Graveur*, vol. ix. p. 316.) as well as those of Amman, whose style they resemble, were chiefly published at Frankfort. They are voluminous. Solis, who was a painter, illuminist, and Engraver, employed artists under him in various departments, and died rich at the age of forty-eight.

Ancient Xylography.

There is a set by Amman (Bartsch, [illegible] p. [illegible]1.) of 115 prints of Arts and Trades, published at Frankfort, 1564, several times reprinted.

2. *Augsburg.* J. Burghmair. Hans Holbein.

In Augsburg, *Johan Burghmair*, the pupil of Albert Durer, executed prints in wood, which approach the fire and spirit of his master.* The father of Holbein was a native of Augsburg, where *Hans*, his celebrated son, was probably born, in 1496. They afterwards removed to Basle. The younger and the greater *Holbein* is said to have practised Wood Engraving as early as 1511, at the age of only thirteen, and to have been employed before his departure from Swisserland by the most considerable publishers of his time at Basle, Zurich, Lyons, and Leyden.†

Sigismund Holbein. Mair.

Sigismund Holbein, his uncle, has some very indifferent wood-cuts ascribed to him. *Alexander Mair*, who flourished about A. [illegible]660, resided chiefly at Augsburg. This [illegible]on [illegible] not be confounded with the Mair of m[illegible], who flourished about 1499, and for whom some German writers claim the invention of Engraving in chiaro-scuro.‡

3. Antwerp. Phillery.

Meanwhile, Antwerp had contributed early to Xylography; a very old print published there is described by Heineken, having the name *Phillery*, with the following inscription in old Flemish characters, "[illegible]print t'Antwerpen by my Phillery de Figursnider," *printed at Antwerp by me, Phillery, Engraver of Figures.*

De Jode. Jegher.

Gerard de Jode, the founder of a celebrated family of artists, was born at Antwerp in 1541. Papillon (*Traité de la Gravure en Bois*, tom. i. p. 229.) mentions some cuts by him, printed at Anvers, in 1566. But *Christopher Jegher*, whose merits recommended him to Rubens for engraving his designs, is the most deservedly celebrated artist in this way that Antwerp can boast. His prints, after that great master, give a very powerful effect, being cut in a bold, free style, with spirited strokes, in imitation of cross-hatchings by a pen. After the death of Rubens, he purchased the greater part of the blocks, and republished on his own account. He worked, also, after the designs of other masters. Among these is a "Crucifixion," after F. Frank, dated 1637.

4. Strasburg. The Stimmers.

The City of Strasburg gave employment to the two *Stimmers* of Schaffhausen; Tobias, and his brother John Christopher, who executed some cuts for the Bible published at Basle by Thomas Guarin, in 1586. Of these prints, which are small, and after the designs of Tobias, it is no inconsiderable proof of merit that Rubens declared he had studied them with attention,

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Heineken, executed these cuts, is to be found at the bottom of the fourth page of the Work, which consists of twenty-four pages, printed on both sides. Nothing can be a ruder performance. See Note (T.) at the end of ENGRAVING.

* V. *Peintre Graveur*, vol. vii. p. 116—197. Ottley's *Hist. of Engraving*, p. 727—736. Two out of the 145 were in a future impression printed in chiaroscuro. (Art. 30.)

† Both these latter sets were eagerly purchased and copied by Marc Antonio on copper, at Venice, who sold them for originals. He affixed the mark of Albert Durer on all but the last plate of the second set, to which he put his own. Bartsch is of opinion (*Peintre Graveur*, vol. vii. p. 18.) that the inequality of execution in the wood-cuts attributed to Durer is so great as to make it improbable that all of them are from his hand. Some of them contain, according to the same Writer, indications more or less decisive of the actual hands which engraved them. A Holy Family (quoting from Merr. *Journal, &c.* tom. vii. p 73.) he attributes to Hans Glaser, a cardmaker: a Madonna to Hans Guldenmund, and the Rhinoceros (Art. 30.) to Hen. Goltzius of the Hague, &c. &c.

‡ See Note (U.) at the end of ENGRAVING.

* *Peintre Graveur*, vol. vii. p. 201. Of the triumph of Maximilian, Bartsch observes, (*Ib.* p. 231.) *Ce recueil consiste en* 135 *pièces qui sont autant de monumens précieux de l'Art de la Gravure en Bois, et qui, par la légèreté et la correction du dessein, autant que par le soin et l'habileté de l'exécution, méritent l'attention et l'approbation de tous les connoisseurs. Ces planches ont été gravées* (p. 235.) *dans les années* 1516, 1517, 1518, *et* 1519, *par dix-sept graveurs en bois très-habiles, sur les desseins de Hans Burgmair dont les lettres H. B. sont marquées sur beaucoup de ces pièces. Les noms des graveurs qui sur le dos d'un grand nombre de ces planches (toutes de bois de poirier) sont tracés à l'encre en toutes lettres ou gravés seulement en monogrammes sur le bois.* Jerome André, Jean de Bonn, Cornelius *ou* Corneille de Bonn, *ou* Corneille Liefrink, Hans Frank, Saint German, Guillaume *et* Corneille Lefrink, Alexis Lindt, Josee de Negher, Vincent Pfarkecker, Jaques Rupp, Hans Schauflein, Jean Taberith, H. F. F. P. *et* W. R. *et* Guillaume *peut-être* Guillaume Lefrink.

† See Note (V.) at the end of ENGRAVING.

‡ See Note (W.) *Ibid.*

Engraving.

and derived much instruction from them. *Christopher Maurer* of Zurich was a pupil of the elder Stimmer.

Maurer.

5. *Amsterdam.* Van Assen.

At Amsterdam, *John Walther Van Assen* and the Van Sichem family were conspicuous. Van Assen was born about 1490. His works are admirably executed, and highly appreciated by collectors. Bartsch mentions twenty-one Scriptural pieces having his mark. (*Peintre Graveur*, tom. vii. p. 444.) Strutt considers him as successful only in the expression of his heads.

The family of Van Sichem.

Of *Christopher Van Sichem*, Strutt informs us that he executed some portraits and other subjects on wood, from Goltzius, which deserve commendation. The prints by *Cornelius* he affirms to be "stiffer and of heavier execution" than those of Christopher: but of the cuts by *Karl Sichem* he expresses no opinion. To Cornelius are attributed more than 600 prints of Scriptural subjects.

6. *Leyden.* Lucas Van Leyden.

Leyden was remarkable for giving birth and fame to Lucas Jacobs, called *Lucas Van Leyden.* (See PAINTING, p. 480.) He was an Engraver, but it is doubted, both by Adam Bartsch and Mr. Ottley, whether he ever engraved on wood; though both these writers give a large list of Xylographic works engraved after his designs.* No works of this kind, however, bear his mark. The only part which Mr. Ottley thinks he might have had in the performance of them was that of making the designs upon the wooden blocks. From the uniform similarity of their execution, Mr. Bartsch considers that Lucas must always have employed the same artist for cutting his designs; and this person was, undoubtedly, of great ability. Lucas died in 1533, at the age of thirty-nine.

Other Flemish artists. Jan Livens.

Jan Livens of Antwerp, the successful follower of Rembrandt in the beginning of the following century, has two wooden cuts ascribed to him, very fine and scarce works. In this Flemish list might be included *Justus Negher*, of Nordlingen, whom Bartsch distinguishes as one of the ablest Wood Engravers in the early part of the XVIth Century; *Peter Koeck* of Alost, the celebrated traveller to Constantinople, who has left us his work of Turkish costumes, &c., dated 1533; *Conrad Meyer*, of Zurich, who engraved some admirable cuts for Erasmus's "Process of Folly;" and *Edward Echman* of Mechlin, who has copied in wood with surprising delicacy and spirit some fine copper-plate prints by Callot. *Ludwig* or *Louis Businck*, who flourished at Minden, according to Heineken, about 1630, executed some spirited prints after his own designs, and those of Geo. Lallemand, his contemporary, of Nancy.

Negher

Koeck.

Meyer.

chman.

usinck.

. *Lyons.* ernard nd Woeiot.

Solomon Bernard was born at Lyons in 1512. Nine sets of prints, most of them for books, printed at Lyons, are attributed to him. *Pierre Woeiriot* of Bar Le Duc, who resided chiefly at Lyons, is described by Papillon as a Xylographer who marked his wood-cuts with a double cross, called the cross of Lorraine.†

Paris and *ouen.*

The XVIIth Century brings us to the remarkable families of Sueur and Papillon at Rouen. *Pierre le Sueur*,* a disciple [illegible] Bellay, was born in 1636. The elder *Papillon*, [illegible] fellow-pupil, was but an indifferent artist; but his son *John*, called the younger Papillon, father to the well-known writer on the Art, and said to have been the inventor of printing-papers in imitation of tapestry, was a good draughtsman and tolerable Engraver. He died at Paris 1723.

Ancient Xylography.

Families of Le Sueur and Papillon.

Compound process of the German School.

(30.) In the first of the two compound processes (Art. 12.) of Xylography, the earliest specimen extant with a date, *viz.* the St. Christopher, has already been alluded to. (Art. 28. Note (O.) at the end.) It was discovered by the Baron Heineken in the Chartreuse at Buxheim, near Memmingen, and is dated 1423. The "Annunciation," another print found with it, pasted in the same book, is considered equally ancient, but is without a date. Jansen alludes to another remarkable specimen in his *Essai sur l'Origine de la Gravure*, tom. i. p. 90. where, after stating first the process of cutting the outline on the block by the *formschneider*, and then the subsequent process of colouring (with a stensil) used by the *briefmahlers*, or card-painters,† he remarks, *c'est exactement de cette manière qu'ont été exécutées les figures de l'Apocalypse à la Bibliothèque Impèriale à Paris.*‡ But respecting the names of these numerous operators nothing is known. He asks (at p. 108.) *mais il s'agit de savoir qui etoient ces ouvriers? On ne connoit par certitude aucun graveur en bois avant Wolgemuth et Pleydenwurff.*

Stensilled prints.

In the other compound process, (Art. 12.) we doubt whether many German artists followed chiaroscuro Engraving exactly in the method which Ugo da Carpi, as we observed, (Art. 28.) is said to have introduced into Italy, namely by means of wood blocks only, and without copper-plate outlines. Bartsch seems to contend that the invention, in any shape, is altogether German. He remarks that a specimen remains of Ugo da Carpi with no earlier date than 1518, but owns that the other prints un-dated from the hand of that master, may (from their being worked with no more than two blocks) be much earlier performances. And then he mentions

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* V. *Peintre Graveur*, vol. vii. p. 438. Ottley's *Hist. of Engraving*, p. 751.

† *Traité de la Gravure en Bois*, tom. i. p. 150, 151. 240. See also Strutt's Dictionary. *Noel Garnier* is mentioned by Papillon without specifying any of his works, as *Graveur en bois fort médiocre*; of *Jollat*, another French Engraver, who flourished about 1510, he particularizes, 58 *estampes gravées en bois assez proprement*, and other works, printed at Paris in 1490. *Jaques Perisin* or Persinus, in conjunction with *J. Tortorel*, engraved the Wars of the Huguenots from 1559 to 1569.

* *Rien*, says Papillon, *n'est plus beau et plus hardi que les tailles de ses gravures. Traité de la Gravure en Bois*, tom. i. p. 303. This Pierre le Sueur had two sons of the name of Pierre; the first, called by Papillon Pierre l'aîné, and, according to the same authority, an excellent artist, was born at Rouen in 1663, and died there in 1698. The next Pierre (*du second lit de l'ancien Le Sueur*) *a gravé en bois passablement à Rouen, mais il manquoit, comme beaucoup d'autres graveurs en bois, de ce bon goût, de cet entente de clair obscur, et de la correction dans les figures que procure l'habitude du dessein. Il est mort environ l'an* 1750. (*Ib.* p. 322.) A third son was born between the two Pierres, named Vincent, of whom Papillon gives the family history, (*Ib.* p. 316—322) and who engraved both in simple Xylography and in chiaroscuro; but was an incorrect draughtsman. He was born at Rouen in 1668, and died at Paris in 1743.

† Cean Bermudez, in his *Diccionario Historico de las Bellas Artes en España*, though he gives no examples of this precise kind, mentions several illuminists, to the number of about twenty, whose works adorn the libraries of the Monasterio del Escorial, and of the Cathedrals of Seville, Toledo, and Segovia. The most ancient are those of Garcia Martinez, belonging to the Cathedral of Seville. He flourished between 1343 and 1381. The most numerous were executed for Philip II., and the latest are by Mosen Eliseo Bonomat, described as *pintor e presbitero*, who died in 1761. Not unfrequently, the process of illuminating resembled what is called, in modern phrase, "oriental tinting," and was practised by means of stensils cut out of thick vellum, tin, or pasteboard.

‡ In the *Book of Trades*, published in 1564, for which we have said (Art 29.) that Justus Amman executed the cuts, the block-cutter, or *formschneider*, is represented in one print, and in another the *briefmahler*, each performing his peculiar and separate process.

various German works with [illegible], three, six, and even nine years previous to 1518.*

Prints in chiaroscuro.

Durer.

H. Baldouin Grün. Pilgrim.

A rhinoceros, imported from India to Lisbon in 1515, was sent as a present by Emanuel, King of Portugal, to the Emperor Maximilian I. Of this animal, Albert Durer made a design, which bears his monogram and the date, 1515, on the original block. Some impressions of this work are printed in *clair obscur* with two blocks. A "Holy Family" and a "Crucifixion" are also enumerated among the *clairs obscurs de deux planches* attributed to *Durer*, but which Adam Bartsch considers doubtful. The "Crucifixion," however, is regarded by Mr. Ottley as a genuine production.† The seventh volume of the *Peintre Graveur* records (at p. 320.) a work by Hans Baldouin Grün, *clair obscur de trois couleurs*. Of *Hans Ulric Pilgrim*, Bartsch particularizes (at p. 449 in the same volume) ten specimens in *clair obscur de deux planches*, and introduces Pilgrim as having the reputation of being the inventor of this sort of Wood Engraving.‡

Altdorfer.

Businck.

"The beautiful Virgin of Ratisbon," after the picture in the Cathedral of that city, is mentioned by Strutt as an admirable work in two tints by *Albert Altdorfer*, whom we before named. (See Note (W.) at the end of ENGRAVING.) Of this work, he adds, that there are some few impressions from the single block on which were engraved the outlines without the half tint. *Louis Businck*, whom we also mentioned before, (Art. 29.) is celebrated for some very masterly cuts in chiaroscuro.

Modern School of Xylography.

(31.) We now come to the Wood Engravers of the XVIIIth Century, to whom, according to the arrangement proposed, (Art. 26.) we give the name of modern masters in Xylography. The number of these artists is so small that they can occupy but a very short space in our columns. In fact, Xylography was given up for a new branch of the Art more effective, and perhaps less difficult of execution: and Copper-plate Engraving, (especially after the superior facilities afforded by the introduction of the etching needle,) began rapidly to supersede the use of prints from wood, even for the illustration of books.

Confined chiefly to Italy, France, and England.

Modern Xylography.

[illegible]tti.

Xylography in the XVIIIth Century, and up to our own times, seems confined to Italy, France, and England. In Italy, a Venetian Nobleman, the Count *Antonio Maria Zanetti*, born at Venice in 1680, became celebrated both as a collector and as an artist. Papillon, his contemporary, born eighteen years after, bears testimony to the beauty of many works of Zanetti in chiaroscuro, *gravures en camaïeu à trois planches ou rentrées depuis 1720 jusqu'en* 1740. They are after drawings by Raffaelle, Parmegiano, and other great masters, most of which the Count purchased at the sale of the Arundelian collection. He was assisted in this work (to which he added several etchings, and which altogether contains eighty-nine prints on copper and wood) by his nephew of the same name, the librarian of St. Mark at Venice. Zanetti has not escaped censure from [illegible] value excellence more than rarity, for his exclusive spirit in burning his blocks and destroying his plates, after taking an inconsiderable number of impressions. Another Italian, and a native of Venice, is *Domenico Rosetti*, who flourished as an Engraver in 1720. He is styled an Engraver in copper as well as wood: and was fortunate in his patrons, the first of whom, an Italian prelate, Giovanni Francesco Barberigo, gave him his education at Verona; and a subsequent patron, the Elector Palatine, by whom he was invited to Dusseldorf, expressed his esteem by gilding the plates (after a few impressions) of the "Triumphs of Alexander."

J. B. M. Papillon.

In France, the activity and ingenuity of *Jean Baptiste Michel Papillon*, son of the last mentioned of that name, (Art. 29.) called the younger, brought the Art into greater notice than had ever been bestowed upon it in that Country. The encouragement which the policy of Louis XIV. had extended to works of taste and to the fine Arts, was not discontinued during the long reign of his profligate successor: and Papillon, like many other men of in[illegible]tive minds, raised himself to fame by the novelty, if [illegible] the solidity, of his pretensions. [illegible]s born at Paris in 1698. Of a bold and independent spirit, with a mind devoted to his Art, and apparently self-educated as to literary pursuits, he put forth his well-known Treatise, historical and practical, on the subject of Wood Engraving: a Work of most amusing *naïveté* and originality, but abounding in historical errors.* His researches, however, are of great extent, and his evidence respecting any fact of which he was personally a witness, is allowed to be perfectly honest and trustworthy by his severest censurers. He was elected, in 1733, member of the Society of Arts at Paris. His Treatise contains many fine examples of his skill in Engraving, where a clear and pleasing effect is produced by single strokes and without cross hatchings. Two specimens are also given of four blocks, each to illustrate his description of cuts in chiaroscuro. His best performances are considered those prints which, in conjunction with Nicolas le Sueur, he executed after the designs of Bachelier, for a fine edition, in four volumes folio, of *Les Fables de Fontaine*. Papillon died at Paris in 1776.

N. le Sueur.

El[illegible]be[illegible] Sueur

Nicolas le Sueur was born at Paris in 1691, and died there in 1764. He was the son of the last-named Pierre le Sueur, (Art. 29.) and is celebrated by his biographer and contemporary artist Papillon, as being remarkable for some very fine cuts in chiaroscuro after Raffaelle, Parmegiano, and others of the high School in Art. These, Le Sueur executed for M. Crozat, for the Messrs. Mariette, for Count Caylus, &c. (V. *Traité de la Gravure en Bois*, tom. i. p. 411.) Papillon adds, that Nicolas would have attained absolute perfection as a Wood Engraver, *si l'autre genre de gravure en bois ordinaire et délicate de vignettes, fleurons, &c. il s'y fut attaché a y donner du feu, du goût, de l'entente, et du clair obscur, mais ses tailles toutes d'une teinte, rendoient ses gravures sans éclat, et sans dégradation ou augmentation de couleur*. The writer likewise commemorates a sister of Nicolas, named *Elizabet*, as a popular artist in Xylography, and acknowledges the assistance which N. le Sueur and himself obtained from the talents of

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* If priority of dates, says Bartsch, is to settle the question, we have the "Rhinoceros" of Albert Durer, A. D. 1515; a portrait after the design of Hans Burghmair, 1512; a portrait of Pope Julius II., 1511; the same date upon "Adam and Eve," after the design of J. B. Grün; and the date 1509 upon a work after Ebend, called "The Witches riding." (*Hexenritt.*) V. *Anleitung*, &c. 1 thiel, sec. 639.

† The "Rhinoceros" is numbered 136 in Ottley, (p. 753.) and 126 in Bartsch. (*Peintre Graveur*, vol. vii.) The "Holy Family" is numbered 10. (*Ibid.*) "The Crucifixion," No. 27 in Bartsch, is No. 132 in Ottley.

‡ See Note (X.) at the end of ENGRAVING.

* To all lovers of autobiography, Papillon's writings are a treasure, and may be classed with those of another most entertaining and kindred original, Benvenuto Cellini.

a pupil named Le Fevre, who, in 1759, or 1760, lost his reason, and became incurable.[*]

Le Fevre.

From France the Art, in its modern state, seems to have crossed the Channel to England, if we put down as the earliest name worth notice, that of *John Baptist Jackson*,[†] who for some time received instructions at Paris from J. B. Michael Papillon, and was employed by him and others in that Capital.

Jackson.

Kirkall.

Edward Kirkall was born about 1695 at Sheffield in Yorkshire. He was the son of a locksmith, and quitted his native town to engrave arms, stamps, ornaments, and cuts for books in London. It appears to us not improbable, that he was the Engraver of several vignettes in a Latin edition, 12mo., of *Terence*, published in London A. D. 1713, and very favourably commented upon by Papillon, (tom. i. p. 323.) who refers to the letters E. K. as the initials of the English Engraver. If this be so, Kirkall, according to the same critic, was the first instructor of Jackson above-named.

The Bewicks.

But the persons to whom modern Xylography is most indebted are two brothers, *Thomas* and *John Bewick*, born at Overton, near Newcastle upon Tyne, whose prints for a *History of Quadrupeds*, published there in 1790, 8vo., first introduced them to the world of Art as original and powerful contributors to its advancement. A *History of British Birds* followed in 1797, but the death of John in 1795 of a consumption had meanwhile dissolved their affectionate partnership. Thomas, however, has lived to transmit through numerous pupils the revival of this branch of Engraving. In 1795 the Poems of Goldsmith and Parnell, published by Bulmer, 4to., are illustrated by these artists; and the year following Somerville's *Chase*, similarly adorned.

Branston.

Robert Allen Branston was a native of Lynn, in Norfolk, who about A. D. 1800, when in his nineteenth year, settled at Bath, as a general Engraver and Herald-Painter. Emulating, however, the reputation of the Bewicks in Wood Engraving, he undertook some cuts for a work descriptive of that ancient city. He found, however, very insufficient support by this occupation, and came to try his fortune in London, where he maintained himself for a while as an Engraver of music. Xylography, however, was by this time reinforced with the talents of *Nesbit*, *Clennel*, and *Hole*, as subsequently by *Bonner*, *Harvey*, *Thompson*, &c., and public encouragement again called forth the industry and eminent graphic powers of Branston. He was employed after this in most of the Xylographic publications of his day till his death, in 1827, at his house at Brompton.[*]

Instruments and materials.

(32.) Before concluding our account of Xylography, some particulars may be expected on the subject of the materials and instruments employed for this branch of Art, and the methods of applying them. These will, perhaps, be best described and understood by introducing, at the same time, a brief reference to the practice of Line Engraving on metal in its simplest form, unassisted by and unconnected with etching or other processes. A comparison between the mode of operation on wood and that on copper-plate (one mode being the exact reverse of the other) may give greater distinctness to both. For the same distinction here exists which was remarked between seals and medals, *sunk* or *caved* work and *raised* work. (Art. 2—5, and note (A.) at the end of ENGRAVING.) The lines which are to receive the ink on the block previous to an impression are so many level ridges standing out in relief, like printers' type; and coming, when printed, into immediate contact with the paper, so as to indent it. The lines on a copper-plate, on the contrary, are so many channels hollowed in the metal, within which the ink is enclosed, and which in printing require the paper to be forced into them, in order that it may come into perfect contact with their contents: and the paper thus pressed will show ridges of greater or less prominency in proportion to the depth of line on the copper. It is manifest, therefore, that for the purposes of Wood Engraving such tools must be provided as will cut away all parts of the wooden surface which are not intended to give impression upon the paper. Knives, gouges, and chisels, of various forms and dimensions for accomplishing this end, are carefully described by Papillon[†] in the second volume of his *Traité de la Gravure*

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[*] Le Fevre assisted in the more delicate touches for the wood cuts published with the *Fables de Fontaine*. Papillon's manner of introducing Le Fevre's malady has led Heineken to presume that poor Papillon himself had at one time impaired his faculties by over-application. *Par un accident commun à plusieurs graveurs*, aussi bien qu'à moi, *Le Fevre est devenu aliéné d'esprit en* 1759 *ou* 1760 *sans avoir pu être guéri : de même qu'un jeune homme nommé Guignard, &c.;* and then he goes on, in his favourite strain of gossip, to relate a similar case. Mr. Ottley looks upon the phrase *aliéné d'esprit*, as a mere pleasantry of expression common to French writers. (*History of Engraving*, p. 23.) This Frenchman, however, is, we think, an exception, and seems throughout his whole book to be too seriously intent upon the subject of it to have any time or inclination for being witty.

[†] The birth-place of Jackson is not mentioned. He flourished from about 1720 to 1754. Papillon accuses him of having ungratefully endeavoured to pass off and sell a surreptitious copy of one of his (Papillon's) Works for his own; a discovery which led to his dismissal, and subsequent want of employment and of subsistence at Paris. (*Traité de la Gravure en Bois*, tom. i. p. 327, 328.) He removed to Rome, and thence to Venice, where he became celebrated for several wood-cuts in imitation of drawings by the ancient masters. A set of seventeen large prints in chiaroscuro was published at Venice by Pasquali, A. D. 1745, in which Jackson, by a new method, undertook to imitate in colours like those of the originals some choice works of Titian, Paul Veronese, Tintoretto, Basano, and others.

"His first essay of this kind," says Mr. Savage, (*Practical Hints*, p. 15.) "was at Venice in 1744, when he published six landscapes." "All the prints in colours that I have seen," adds the same writer and artist, "show a failure; for the oil which he used in the ink has not only stained the paper on which the subject is printed, but also the adjoining leaves." Mr. Savage goes on to remark that the use of oil in coloured printing inks not only defaces the paper, but changes the colours. We may subjoin, that a similar fault very painfully appears in the chiaroscuro specimens of Papillon. See Note (M.) at the end of ENGRAVING.

From Venice Jackson returned to England, where probably he died. Among Jackson's prints in simple Xylography is a "Descent from the Cross," after Rembrandt, conveying, says Strutt, in a spirited manner, a good idea of that great master's mode of sketching.

[*] Some of the best specimens of the modern English School of Wood Engraving are to be found in a volume entitled *Religious Emblems*, published in 1810 by Mr. Ackermann, of the Strand, London. The Work also of Mr. Savage, alluded to in the preceding note, is remarkable, and contains, together with some aspiring attempts in chiaroscuro, which have failed through their excessive complexity, several of the finest productions from the burins of Branston, Nesbit, Bonner, Thompson, &c. after drawings by Thurston, Callcott, W. M. Craig, W. H. Brooke, J. Varley, W. Hunt, J. P. Neale, &c. Mr. Savage mentions J. Skippe, Esq., an amateur, among the improvers who had preceded him, of coloured Wood Engraving in cameo. For examples of modern skill and patience in cross-hatching, see the *Typographia* of Mr Hansard.

[†] See Note (Y.) at the end of ENGRAVING. The author of a modern Work on Decorative Printing observes, that the improvements which have taken place since Papillon wrote have nearly superseded the practical parts of his book. Savage, *Practical*

en Bois, (tom. ii. p. 11—47.) together with the proper ways of sharpening and adjusting them.

Method of printing wood-cuts differs from that of copper-plate Engravings.

Another main point of difference between these two branches of Engraving is seen in the mode of taking off impressions; wood prints have the capability of being placed in the body of a printed work surrounded by the letter-press. They receive their share of the same ink with which the types are coloured, and can be printed at the same moment with them. Metal plates, on the other hand, incur the additional expense and labour of separate printing, by means, generally, of pressure between two cylinders and in a press of peculiar construction. The superiority, too, of wood over metal as to durability is remarkable.*

CHALCOGRAPHY.

Ink impressions from metal plates how discovered and when.

(33.) The invention of taking impressions from engraved plates of metal has been described by Vasari in

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Hints, p. 63. See also Note (M.) at the end of ENGRAVING. The instruments now employed by Engravers on wood are generally similar and similarly handled to those of Engravers in copper. A tool of the same kind, and sometimes of exactly the same form with the common graver or burin, (see Note (B.) *ibid.*) was probably first introduced by John and Thomas Bewick. It is held in the same manner as for Engraving on metal. Sometimes, too, the edges which cut away the wood are rounded; (pl. i. No. 3,) sometimes squared, (*Id.* No. 4,) similarly to the occasional instrument of the Chalcographer; and sometimes the whole of the steel bar is of a rounded or cylindrical form.

Various sorts of wood have been used in this Art; occasionally pear tree, lime, sycamore, and other soft woods; but the only material in use at the present day is box. The wood, too, is not now cut into *planks* as formerly, (namely, with its grain parallel to the engraved surface,) but into *rounds*, or transverse sections, so that the engraved surface must always lie at right angles to the grain, and present, in every part of it, a uniform resistance to the edge of the tool employed. Thus is gained an advantage tending essentially to accuracy as well as facility of execution. The box tree grows in Turkey to a size considerably larger than in this Country. See *Isaiah*, xli. 19. and lx. 13. where the fir tree, the pine, and the box tree are mentioned together as forest trees, and styled the Glory of Lebanon. The Turkey box is consequently a frequent article of importation; but for small works and vignettes our English boxwood is excellent. A species from America, larger than that from Turkey, has been tried but not found so good. The rounds or transverse sections of the tree are sawn nearly an inch in thickness, so as that in printing they may be brought to lie evenly with the type. Each block is next carefully scraped and polished to a degree of smoothness proper to receive the drawing; and the drawing generally is made upon it by the original designer either in pencil or with a pen. Frequently it is shaded with Indian ink or seppia in a very finished manner, giving the fullest effect of chiaroscuro of which the artist is capable, and leaving to the Engraver his choice of whatever kind of lines (Art. 14. 15.) he has found by experience to be most effective.

* Where any tolerable care is taken by the Printer, one hundred thousand or one hundred and fifty thousand impressions may be taken from a Wood Engraving without material change to the block; whereas from copper-plate, although engraved deeply and with a high burin, scarcely three thousand perfectly clear impressions can be obtained. From copper-plate, says M. Bartsch, executed throughout with high burins, the first fifteen hundred impressions taken are generally perfect; the next fifteen hundred become gradually more and more defective in harmony; and the remaining thousand are altogether grey, monotonous, and feeble. Plates worked superficially, *i. e.* with the low burin, give one thousand impressions less. (*Anleitung, &c.* vol. i. p. 11.) Even a steel plate will not give more than ten thousand without betraying evident marks of the wear occasioned by rubbing the colour (according to the same process as with copper) into the engraved lines, and at the same time clearing it away entirely from the surface of the plate previous to each impression. To this friction the wood block is not exposed. The only friction to which the block can be subjected, besides that from the ink roller or dabber in charging it with ink, or from the pressman in printing, arises from the operation of cleansing it after use. Papillon (*Traité, &c.* vol. ii. p. 375.) recommends for this latter purpose a soft brush, in form like a hat brush or brush for shoes; it must be dipped in a lie made by boiling half a pound of pearl ashes in three pints of water, and then passing the liquid through a linen strainer. The ink immediately on application of the brush quits its hold of the block, which must then be further cleansed by the application of clean water and a clean sponge. If the liquid be warm its cleansing virtue is more active. Mr. Savage recommends, instead of the lie, spirits of turpentine; (*Hints, &c.* p. 46.) and Papillon, *faute de cette drogue*, (alluding to the pearl ashes,) recommends warm water and common soap, not, however, of an acrid quality: otherwise fresh water must be applied. Great care must be taken in drying the block, so that it shall not be warped. This is often the case with large cuts if left all night upon the press stone. "Let them be laid," says Mr. Savage, "with their faces downwards upon the imposing stone with a few thicknesses of damp paper underneath, to place the flat side of a planer upon them: in the course of six or seven hours each block returns to its former state." (*Ibid.*) Much application of water in cleaning the block or otherwise should be avoided if possible. Persons careless of this rule have been known to steep a block in water in order to cleanse it; and by this steeping are sure to swell the lines of the print. Papillon is so nice upon this point, that in order to avoid the effects of moisture from the breath in Engraving, he advises the artist to wear on his chin a covering or guard, to which he gives the name of *mentonière*. (vol. ii. p. 56.)

The friction, on the other hand, in printing from copper-plate is considerably greater than any to which wood-cuts or type can be exposed. And that this friction must occur between each impression is evident from the following description by Mr. Hansard. (*Typographia*, p. 802.) "The workman takes a small quantity of the ink upon a rubber made of linen rags strongly bound about each other, and with this smears the face of the copper-plate as it lies on a grate over a charcoal fire. (Here the writer states in a note the invention by Mr. James Rainshaw, approved and rewarded by the Society of Arts in 1818, for heating the plates by steam, and thus avoiding the noxious fumes of charcoal.) The plate being sufficiently inked, he first wipes it over with a foul rag to take off the extra colour; then with the palm of his left hand, and then with that of his right, he continues to free the surface of the plate from all the unnecessary ink which it had received; and to forward this operation of wiping he dries the inside of his hands from time to time by rubbing them on a lump of whitening. In wiping the plate perfectly clean without taking too much ink out of the strokes consists the practical proficiency of the workman in his Art. The plate thus prepared is next laid on the plank of the press, and upon it is placed the paper, moistened in the same manner as for letter-press, in order that it may more freely receive the ink and impression. Two or three folds of flannel are then brought over the plate, and things being thus disposed, the press is set in motion by pulling the arms of the cross, by which means the plank bearing the plate and paper is carried through between the rollers, which pinching very forcibly and equally press the moistened and yielding paper into the strokes of the Engraving, whence it draws out a sufficient portion of the ink to display every line of the intended print."

Printing from steel plates is perfectly similar; so that the quantity of friction must mainly contribute to efface the Engraving from a surface of either metal. The discovery, however, by a celebrated American, Mr. Jacob Perkins, of multiplying engraved steel plates by means of steel cylinders, seems to set at nought the powers of wear and tear and of time. A steel plate is first softened to such a degree of ductility as will permit the artist to use the finest tools with nearly the same ease as if he were engaged on a copper-plate. When his Engraving is finished, the plate is hardened by a process of carbonization, and is then not only capable of producing from the press a hundred times as many impressions as a copper-plate would yield, but is also made instrumental to the formation of other plates almost *ad infinitum*, by a transfer, mechanically, of the Engraving to those other plates, so that each new plate becomes a perfect fac simile of the first. The transfer is made by rolling a cylindrical piece of softened steel over the hardened plate with a pressure sufficient to give the cylinder a complete impression in *relievo*. The cylinder, being then hardened, is used for transferring the subject to any required number of plates, each of which may be again employed for the same process in a course of endless reproduction.

But, again, as a set-off against this method of giving imperishable permanency to the labours of the burinist, the Wood Engraver enjoys the advantage of *stereotyping* his productions. The impressions from the fac simile, in type metal, of his Wood Engraving may be multiplied to millions and tens of millions of copies, while the original block remains entirely inert and perfect, and liable to no other friction than has occurred in forming the first mould. Of

Finiguerra.
Baldini.
Botticelli.
Pollajuolo.

Thomaso Finiguerra, whom we have mentioned, (Art. 33.) and who is said to have been born about A. D. 1424, communicated his discovery of impressions from metal to another goldsmith, his fellow-townsman, and his junior about twelve years,* *Baccio Baldini*. Vasari's account of Baldini is extremely brief, and only mentions him as being an inferior draughtsman, indebted for designs to the pencil of *Sandro* or *Alessandro Botticelli*, another contemporary goldsmith, who had some celebrity, both as a Painter and Engraver. A much superior artist, however, (particularly as regards the naked figure,) was another Florentine goldsmith, *Antonio del Pollajuolo*, born in 1426, who died in 1498. He was one of the most eminent of his time in Painting and Sculpture.†

Gherardo

Another Engraver of this period is *Gherardo*, a miniature painter of Florence, and worker in mosaic, whom Vasari mentions as having shortly before his death (which happened about 1490) taken up Engraving in imitation of the German style of Martin Schöngauer.‡

Robetta.
Leonardo da Vinci.

Robetta is another name slightly noticed by Vasari.* Among these Florentine artists, *Leonardo da Vinci* is thought to have exercised the graver. An interesting specimen has been preserved in the cabinet of Thomas Wilson, Esq., of which a fac simile is prefixed to a Work descriptive of that gentleman's unique collection, entitled *Catalogue of the Prints of an Amateur*, 4to. London, 1828.

Andrea Mantegna.
Giulio and Domenico Campagnola.

Meantime the Venetian States and the other Northern districts of Italy were not wanting in contributors to the advancement of the new Art. It is even doubted whether the next named artist did not precede the School of Florence in the publication of Engravings. *Andrea Mantegna*, born near Padua in 1431, whose celebrity as a painter we have already noticed, (PAINTING, p. 475—478.) was one of the earliest practisers of Line Engraving, and did more towards its progress in Italy than perhaps any of his contemporaries by his superior knowledge of design. Mantegna died at Mantua in 1506.† *Giulio* (Julius) *Campagnola*, (born 1498,) and *Domenico Campagnola*, of the same family, (who flourished in 1517,) the latter one of the best of the early scholars of Titian; the former the undoubted improver and (by some) reputed author of the dotted method of Engraving,‡ contributed jointly with Mantegna to the fame of their native Padua.

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* Mr. Ottley places the birth of *Maso Finiguerra* about A.D. 1410. Maso died at Florence at an advanced age. His discovery is dated by Heineken A. D. 1460; but a much earlier date (A. D. 1440, or even a few years earlier) can now scarcely be denied to it ever since the Abbé Zani's good fortune in finding among the ancient prints of the National Cabinet at Paris an identical impression taken off by Finiguerra himself from the silver Pax already named in the last note as belonging to the Church of San Giovanni at Florence, and representing the Coronation or "Assumption of the Virgin." Its perfect resemblance to the sulphur in the possession of his friend the Count Seratti drew the Abbé's first attention to it; and his joy in afterwards ascertaining fully the genuineness of the production, is expressed with a zeal most unaffectedly characteristic. See his account of the transaction published at the time, and translated in Mr. Ottley's Work. "The workmanship of the Pax," observes the Abbé, "which Finiguerra probably began in 1451, (the plate is registered 1452 in the archives of the Church it belongs to,) fully shows that he must have been at that time not merely a man greatly advanced in his Art, but a master of high credit and reputation." It has been well remarked that M. Mariette, who had the charge of the collection of the King of France, and who consequently held this remarkable print under his key without knowing it, boasted vainly of connoisseurship while corrresponding A. D. 1732 with Cav. Gaburri of Florence, about the origin of Chalcography, while he left this document unnoticed, and only kept this valuable relic of Italian Art to be discovered by a foreign amateur in 1797. Mr. Ottley, at p. 308 of his Work, presents his reader with a fac simile of Zani's discovery; and also at p. 304 with another print, a fac simile, after one in his private collection, and regarded by him as a proof impression from some work of niello, probably by Finiguerra or some Florentine artist about the middle of the XVth Century.

† A few characteristic fac similes from the works of Baldini, as well as from those of Botticelli and Pollajuolo, are given by Mr. Ottley, vol. i. of his *Hist. of Engraving;* where likewise will be found a translation of Vasari's Life of Botticelli, with an examination of his works and merits. Botticelli was born at Florence in 1437 and died there in 1515. The Engravings for the edition of Dante, printed at Florence by Nicolo di Lorenzo della Magna, in 1481, are from the burins of Baldini and Botticelli. But a previous publication had appeared in 1477, entitled *Monte Santo di Dio*, with engraved illustrations, probably by the same artists. This is thought to be the first book embellished with copper-plates, of which the precise date has been ascertained.

‡ Mr. Ottley (*Hist. of Engraving*, p. 457.) introduces a subject, "The Assumption of the Virgin," as probably from the burin of Gherardo, and remarks of it, that the shading (which in the Engravings ascribed to Baldini is for the most part effected by close hatchings crossing each other in various directions, but without curvature) is here represented by fine curved strokes, terminating, in many instances, on the light parts of the figures, with dots or other short delicate touches of the burin in the manner used by Martin Schöngauer and other ancient Engravers of the German School. We learn from Vasari that the prints of Schöngauer found their way into Florence in considerable numbers many years before the end of the XVth Century.

* He is named only as member of an artist's club at Florence, called "La Compagna del Paiuolo," founded by his friend Giov. Francesco Rustici, about 1511 or 1512. The Society met alternately at each other's houses, to converse on the Arts, and to sup together. The works of *Robetta* prove him, says Mr. Ottley, (who gives an account of twenty-eight Engravings by him,) to have been no ordinary goldsmith. In small draped figures he is frequently graceful, but is not successful in the naked figure. He also sometimes introduces a few dots or short curved strokes after the manner of Schöngauer into his shadings, which appear finished with close hatchings thrown in various directions. Bartsch enumerates twenty-six plates by this artist, but erroneously dates their execution so late as the year 1520, contrary to Huber, Ottley, and others, according to whom he flourished about or before the time of the Society of artists above mentioned.

† In those days nothing better was expected in an Engraving than that it should perfectly resemble a pen and ink drawing: and this imitation seems to have been the utmost aim of *Mantegna*. His plates are generally shaded by single strokes or parallels in a diagonal direction across the plate, without cross-hatchings. In this respect they are like those of Pollajuolo, but with figures still better drawn, and are executed in general after admirable designs of his own. His works do honour to his instructor and patron, Francesco Squarcione, of whom the Abbé Lanzi observes, that if he was not himself the best artist of his day throughout the State of Venice he was certainly the best qualified to teach others. M. Bartsch gives a *catalogue raisonnée* of twenty-four subjects by Mantegna, and his authority is quoted by Mr. Ottley, who states his opinion that Mantegna was early initiated in the Art, and engraved several studies of his painted works some time previous to their appearance on canvass.

‡ Of *Giulio* only nine pieces are recorded by Mr. Ottley, and of *Domenico* twelve. M. Bartsch, (*Anleitung*, &c. sec. 386, 521. Ed. 1821,) describing certain works executed by dots, (*mit der goldsmieds-punze*,) records a plate executed in the finest style of punching, the work of Giulio Campagnola, and says it may be considered the first attempt at this style. Giulio, he adds, composed it after another copper-plate from the burin of Girolamo Mocetto, (Art. 27.) but has reversed the figures and substituted a new back-ground. A fac simile of this plate, which represents "John the Baptist in the Wilderness," is given opposite page 768 of Mr. Ottley's *Hist. of Engraving*. Another earlier print in this style, with the initials P. P., is noticed in Mr. Ottley's *Enquiry, &c.*, p. 474. The *Catalogue of an Amateur*, however, alludes to an Engraving of the "Virgin and Child," described as a dotted specimen of the early German School, which perhaps may claim precedence of both the plates first mentioned; though Giulio Campagnola seems undoubtedly the first who brought this method of operating to any degree of perfection.

Bramante d'Urbino.

Mocetto.

B. Montagna.

In the State of Milan, *Bramante d'Urbino*, best known as an architect, directed his powers to fresco Painting, and the use of the graver. He died in 1514. Verona gave birth to *Girolamo Mocetto*, whom we have before mentioned, (Art. 27.) and Vicenza, nearly at the same time, to *Benedetto Montagna*, who flourished about A. D. 1500: also, probably, to *Marcello Fogolino*.[*]

ltobello nd others.

Other names might be added to complete the early School of Italy, as *Altobello*, a scholar (according to Padre Testa) of Bramante, and whom Vasari relates to have painted with considerable ability a life of Christ conjointly with Boccaccio Boccacini in the Duomo of his native city Cremona; *Nicoleto da Modena; Giovanni Batista del Porto; Giov. Maria da Brescia;* and his brother *Giov. Antonio.*[†] *Beccafumi*, the Wood Engraver, (Art. 28.) also performed occasionally on copper and with the graver only. We might here also mention, if our limits permitted us, various unknown Engravers of Italy whose works are distinguished only by ciphers and monograms.[‡]

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urc An- iio Rai- ndi.

(36.) We now arrive at a period (the XVIth Century) when the Art of Copper-plate Engraving was to receive and to deserve greater encouragement in Italy, and when its progress became in some degree proportioned to the advancement which Painting at the same time manifested under the great founders of the Italian Schools. A celebrated Bolognese goldsmith named Francesco Rabolini, but oftener Francesco Francia, who engraved medals admirably, as well as some fine productions in niello, had also practised Painting with success in his native city. Among his principal scholars were his son *Jacomo*,[§] and *Marc Antonio Raimondi*, born likewise at Bologna A. D. 1487 or 1488. Marc Antonio became, as Vasari relates, a more skilful designer than his master, and was an invaluable assistant in such works of niello as were fashionable at that time for ornaments in dress, &c. He quitted, however, the service of Francia to try his fortune at Venice, where we have already traced him copying upon plates of metal some woodcuts of Albert Durer.[||] (Art. 29. *Nuremburg.*) From the handling of Durer, Marc Antonio, already an expert burinist, was not the less eager to derive new lights. His object was to improve himself in every department of his Art; and when a print, very neatly engraved by him at Rome, "Lucretia," after a design of Raffaelle, became the means of introducing him to that great master, he was placed in a situation which every Engraver since must have envied him, and which of all others was the best and happiest for his purpose. During the short lifetime of Raffaelle, (born A. D. 1483, about eight years before him,) Marc Antonio was employed continually by that eminent master, who despatched to Albert Durer many of his prints as presents, and who frequently corrected his designs on the plates, or perhaps even assisted in their execution. Otherwise there seems no accounting for the exquisite identity with which the character of Raffaelle's pencil is preserved.[*] Among the numerous scholars of Marc Antonio, *Agostino Venetiano* and *Marco di Ravenna* were the two most celebrated. From the School, indeed, of this remarkable Engraver went forth professors who established his principles, not only in Rome, Venice, Parma, Mantua, Bologna, Ravenna, and other cities of Italy, but in some parts of Germany and the North of Europe.[†]

His pupils, German as well as Italian.

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[*] A specimen of this master's rare and almost unattainable productions is recorded (*Catalogue of an Amateur*, p. 37.) in the collection of Thomas Wilson, Esq., a gentleman proud to claim and worthy of claiming kindred with our celebrated Countryman Richard Wilson, for whom see PAINTING, p. 496.

[†] *Giovanni Maria* flourished, as appears from his few prints, A. D. 1502. He was a goldsmith, a Painter, an Engraver, and an Ecclesiastic of the Order of Carmelites at Brescia, and, according to Orlandi, enriched the cloisters of that Convent with several fresco pictures. His brother Antonio is remarked as being more of a professed artist; and in his early works (some executed before A. D. 1500) adopted the style of Andrea Mantegna, but in some of his later productions imitated Marc Antonio Raimondi. He sometimes copied in reverse the prints of the latter, sometimes those of Albert Durer, and seems to have engraved frequently after drawings or pictures by Raffaelle d'Urbino or his School.

[‡] Such works as are extant, both of these and the before-mentioned artists, are carefully described in the fifteenth volume of M. Bartsch's *Peintre Graveur*, and in Mr. Ottley's *History of Engraving*, p. 511—593. Among the "unknown," for example, is the "Master of the Caduceus," so called from his monogram, of whom twenty-four pieces, in a style resembling the School of Ferrara, are recorded.

[§] To *Jacomo* Mr. Ottley attributes eight Engravings which he describes, *Hist. of Engraving*, p. 772.

[||] "It happened," says Vasari in his Life of Raimondi, "that at this time certain Flemings came to Venice with a great many prints engraved both in wood and copper by Albert Durer, which being seen by Antonio in the Piazza di S. Marco, he was so much astonished by their style of execution, that he laid out upon these prints almost all the money he had brought with him from Bologna." The attention, indeed, of artists in Italy had for some time been drawn to the progress of their German and Dutch rivals, who, though inferior to them as to graces of contour and chaste simplicity of design, yet went far beyond them in execution, and what is termed "delicacy of burin."

[*] These corrections might easily be made by Raffaelle with a dry point marking the intended course of the graver. Mr. Ottley concludes his *Hist. of Engraving* with an enumeration of three hundred and fifty-nine subjects engraved by *Marc Antonio*, and M. Bartsch, in vol. xiv. of his *Peintre Graveur*, (from which the catalogue is formed,) gives a description both of these Engravings and of the various copies of each print, together with a similar account of the numerous works of *Agostino Venetiano* and of *Marco di Ravenna*, his celebrated pupils.

[†] Among the foreign scholars of Marc Antonio, *George Pencz*, who passed his youth at Nuremburg, and his latter years at Brescia a former pupil of Albert Durer, was so far converted to the style of his new master as to be the author of works that resemble the best manner of Raimondi. The *Behams*, Bartholomew and Hans Sebald, (the latter a nephew and pupil of the former,) conveyed similar lessons in Italian Chalcography to Frankfort and Nuremburg; while *James Bink*, another German pupil of Marc Antonio, and native of Cologne, dispersed the same precepts as far as Konigsburg and the Court of Prussia, where he latterly resided. Of Bink, however, it is recorded that he never entirely relinquished the manner of the German masters.

But our business here is chiefly with the Italian pupils and followers of Marc Antonio. *Giulio Bonasone* was born at Bologna about A. D. 1498, and *Agostino de Musis* (above alluded to under his popular name Venetiano) at Venice about 1490. Strutt particularizes seventeen of Agostino's principal performances, and represents him as the introducer of that method of Engraving which is performed by dots only. So that he as yet divides the honour of that invention with Giulio Campagnola. (Art. 35.) Instead of parallel lines, Venetiano frequently uses dotted shadings on the naked parts of his figures. With whatever artist this practice originated, it was evidently the foundation of what moderns term *stippling*, or the *chalk manner*. Venetiano left two sons, *Lorenzo* and *Giulio de Musis*, who imitated, but with no great success, the style of their father. *Marco Ravignano*, so called from his birthplace Ravenna, (born about A. D. 1496,) but whose family name the indefatigable Abbé Zani discovers to be Dante, was an early intimate and fellow-student with Venetiano. During the life of Raffaelle, Marco di Ravenna and Venetiano worked jointly under their preceptor Marc Antonio, but after Raffaelle's death their plates are separately marked and dated, and show each to have been employed from that time on his own individual account. Of Di Ravenna it is observed that he marked but feebly the extremities of his figures. He died at Rome about 1550. *Giov. Giacomo Caraglio* was an Engraver worthy of the Marc Antonio School: He was born at Parma about A. D. 1500, but subsequently settled

(37.) When it is considered that the principles of chiaroscuro and the representation of local colour, as connected with Engraving, were at this time unknown, the progress of Marc Antonio Raimondi entitles him to our unqualified admiration. Italy, indeed, was now to become, in the eyes of applauding Europe, the only proper theatre for pictorial study; and a kind of mania, upon which we made remarks in another place, (PAINTING, p. 480.) prevailed among foreign artists, especially of the Dutch and Flemish Schools, for visiting this nursery of genius, and for being rocked in the Italian cradle. The result was fortunate for the Italian School of Engraving.

Cornelius Cort.

Cornelius Cort, born in 1536 at Hoorn in Holland, whose first instructor in the Art appears to have been Jerome Cock, an Engraver and Printseller at Antwerp, (and who engraved in early life several plates published there under the name of his master, as well as several others afterwards from various Flemish masters on his own account,) caught the general rage for travelling; and, ambitious of extending his artistic knowledge, undertook a journey to Venice, where for some time he resided in the house of Titian, and engraved some of Titian's finest pictures. He now rose superior to his former efforts, and adopted that characteristic breadth of manner to which chiaroscuro, neglected by his predecessors, was indispensable. Subsequently he settled at Rome, and established there a School which opened new means of improvement to the burinists of Italy.* Of his plates (more than one hundred and fifty in number) M. Heineken gives an ample account. He died at Rome at the age of only forty-two, when his reputation was at its highest, A. D. 1578.

His pupils, Ag. Caracci and others.

The most remarkable pupil of Cornelius Cort in Italy was *Agostino Caracci*, born at Bologna A. D. 1558, the eldest of three celebrated brothers brought up under their extraordinary cousin Ludovico. (PAINTING, p. 476.) Agostino was intended by his father for the business of a goldsmith, a business in that age connected, as we have seen, (Art. 36.) with the Art of Engraving; so that the young Engraver, when only fourteen, contrived to execute, in the style of Cort, some plates, at sight of which his cousin persuaded him to study Painting. M. Bartsch reckons the engraved works of Ludovico to amount in all to more than two hundred and seventy. He died in 1602. Of his pupils and followers, the two best were *Francesco Brizzio*, his fellow-townsman and friend, and *Giacomo Franco*, born at Venice about A. D. 1500; but Agostino for beauty, for outline, and for expression, left no burin behind him to be compared with his own.*

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at Verona. *Enea Vico*, also of Parma, whose history we have abridged, (Art. 27. p. 738.) was another student who passed some time under Marc Antonio at Rome. M. Bartsch, who gives a descriptive list of four hundred and ninety-four pieces by Vico, contends that this artist confined himself to Engraving on metal; that he adopted at different times the several styles of the four last-mentioned artists, and that only about A. D. 1550 he formed a manner of his own, which was distinguished by delicacy and neatness even to excess, but that he never, as Huber reports of him, engraved at all on wood. He died about A. D. 1570. Of the same period and of the same School with Vico, were four remarkable Engravers from the family of *Ghisi* of Mantua: *Giovanni Batista Ghisi*, *Diana* his daughter, together with *Georgio* and *Adamo*, believed to be his sons. The style of Ghisi, the father, bears, in the opinion of M. Bartsch, an especial resemblance to that of an anonymous Italian Engraver who marked his plates with the letter B upon a small cube; and is thence called the *Master of the Die*. Some of his plates have the letters B V without the cube, and the V has been thought to stand for Venetiano. The prints by this "*inconnu*" are admirably designed and beautifully engraved. His burin is extremely like that of Marc Antonio, whose disciple he probably was; and the only fault imputed to him is, that his figures want height, so that their heads look too large and their limbs too strong and muscular for their bodies.

* He engraved at Rome the greater part of those prints which have been called with truth the delight of every judicious collector. The Art hitherto had nearly been confined to small plates, but the style of Cort, open, grand, and forcible, in which boldness and freedom are seen combined with delicacy and clearness of effect, was adapted peculiarly for "subjects of large dimensions." Not only is his outline vigorous and correct, but his masterly handling has called forth from Basan (*Dictionnaire des Graveurs*) the affirmation that Cort was the best Engraver with the burin only that Holland ever produced. Strutt, however, says of him, that his burin was unequal and sometimes even slovenly; but he cannot withhold his praise from Cort's "lightness of touch" in engraving landscapes without the assistance of the point. In a "Transfiguration" after Raffaelle, Strutt remarks, that this Engraver has greatly failed, and that the character and expression of the heads, so admirable in the picture, are quite lost in the Engraving. Cort also engraved after Michael Angelo, Andrea del Sarto, M. Hemskirk, Franc. Floris, and others. His first works before he left Holland appear to have been after Hemskirk. Bible subjects, very indifferently executed.

Until the time of Cort, says M. Bartsch, (*Anleitung*, &c. vol. i. sec. 400.) Engraving had only been executed in closely compacted lines. Cort was the first who introduced a broad style of handling for the representation of drapery intelligibly, and according to its texture. (Art. 18.)

* *Agostino*, following the advice of his cousin *Ludovico*, studied painting some time at Parma, with his brother Annibale, and thence proceeded to Venice, where he perfected himself as an Engraver by the instructions of Cornelius Cort. He adopted the bold and free method of his preceptor, but in drawing was beautifully superior. His heads, observes Strutt, are admirable, and the marking of his extremities the most accurate and masterly; but his draperies are often stiff and crossed with a square second stroke which gives them an unpleasing effect. But perhaps his greatest defect is the prevalent fault of that Age, namely, the little attention paid to the chiaroscuro.

Another Italian scholar of Cort was *Francesco Villamena*, born at Assisi about A. D. 1560, who died at Rome A. D. 1626. He seems, says M Bartsch, to have been too sparing of his graver; for his prints give the idea of sketches rather than of complete pictures. His lights being diffused too equally over a whole subject produce a slight and unfinished appearance: so that he may be said to be clear rather than powerful.

Batista and *Giacomo da Parma* might here be mentioned, (the former born at Parma about 1530,) an imitator of Cornelius Cort; the latter somewhat resembling Caraglio. (See last note to Art. 36.)

Martino Rota, born at Sebenico in Dalmatia about A. D. 1540, seems to have taken Cort for his model, and has copied the "Christ tempted in the Wilderness," from an Engraving by that master. He resided chiefly at Rome and Venice. His figures are correct in their design, but their extremities are not always duly marked. *Beaucoup de ses estampes*, says M. Bartsch, *ne font pas l'effet désiré à l'égard du clair obscur, parceque suivant le goût de la gravure de son temps, il n'a pas assez soigné les demi-teintes, et les dégradations dans les tons.* His print of the "Last Judgment" after M. Angelo is his chef-d'œuvre, and would, if he had engraved nothing else, suffice to rank him among the ablest Engravers of his time. But his portraits, among which may be particularized those of the Emperors Ferdinand I. and Rodolph II., leave far behind all that had been done before in this way by Beham, Pencz, Aldegrever, and the other old masters.

We doubt whether to this list of Italian names in simple Chalcography we need subjoin that of an inferior artist, *Giov. Bat. Boncini*, a native of Milan about A. D. 1520, who seems to have trained in the School of Cornelius Bloamaert; or the names of *Lucas* and *Cristofolo Bertelli* and their kindred at Modena, a tribe of dry and laboured and unsuccessful imitators of Cort. Two descendants of a family at Strasburg, the *Greuters*, father and son, had some reputation at Rome, where the latter was born about A. D. 1600. But we conclude with a name, mentioned by M. Bardon with some praise, namely, *Giovanni Marco Pitteri*, born at Venice in 1703, a pupil of Giov. Antonio Faldoni, whose style he did not adopt but contrived a method of his own quite distinct from the whim of Mellan. (See Note (G.) at the end of ENGRAVING.) His style is somewhat mannered, but, being a learned draughtsman, he has

Old German School of Chalcography with the burin only.

(38.) The **German School** of early Chalcography has handed down to us impressions so superior to the Italian, that many writers on the subject, whose criticism (and such is the criticism of Strutt) being unincumbered by national prepossessions seems impartial, have ascribed to Germany a simultaneous if not prior discovery of the Art. The year 1460 is mentioned by Vasari as about the date of Finiguerra's invention. (Art. 35.) The German School commences, however, with an anonymous Engraver, who dates so early as A. D. 1466.[*] The wonderful ease of execution to be remarked in these prints from the burin of the *Master of 1466*, as he is generally styled, leads to an inference that a number of anterior prints must have proceeded from the same hand in order to the acquirement of so much experience and facility.[†]

The Master of 1466 Martin Schöngauer.

It is considered that the style of this Master of 1466 had several followers. Of these we shall speak anon after mentioning another original artist who has been regarded also as the introducer of a peculiar and separate style; namely, *Martin Schön*, or *Schöngauer*, born, as it is now well ascertained, at Colmar, A. D. 1453, where he died in 1499. His family, however, were from Augsburg. He was a painter of great celebrity in his time, and according to Sandrart was the intimate of Pietro Perugino, the master of Raffaelle. The story too, which Vasari narrates, that Michael Angelo, when a boy, copied in colours, as a chef-d'œuvre, one of Martin's prints, the "St. Anthony tormented by Devils," has been told in compliment to this Engraver. The style of Schöngauer, notwithstanding its Gothicisms, has been awarded due praise for great powers of expression.[‡]

Their followers.

Among the followers of the Master of 1466 Strutt reckons *Israhel van Mechen*, or *Mecheln*. M. Bartsch, however, who gives a list of two hundred and thirty-three undoubted pieces by this artist, includes among them not less than forty copies from the plates of Martin Schöngauer. Of Israhel van Mechen, he observes, (*Peintre Graveur*, vol. vi. p. 196.) that "his works bear the Gothic stamp of his times without any redeeming beauties; that he stands therefore below Schöngauer and his other contemporaries, whose works show an originality and a fire which shine forth frequently through a crowd of awkward and disagreeable particulars; and that no artist has ever copied one of Israhel van Mechen's plates." Strutt, however, maintains that Israhel had several disciples; and amongst them instances an artist named Zwoll, or Zwott, whom M. Bartsch identifies with an anonymous Engraver called, after his monogram, the *Master of the Shuttle*. He enumerates eighteen pieces by this master, which, if they answer Strutt's severe description of them, prove Zwoll to have been at least a faithful disciple of Van Mechen.[*]

Israel Van Mechen.

The Master of the Shuttle.

Schaufflein, Van Bocholt, and others.

The other class of early copper-plate Engravers, followers, according to Strutt, of Martin Schöngauer, are: first an artist whose mark B. S. in Gothic character he interprets Bartholomew Schön.[†] After him *Schanfflein* the elder;[‡] *Franz van Bocholt*;[§] *Bosche*, (or rather

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made it answer his purpose. Instead of working in the usual mode by lines crossing each other in various directions, he covered his plate with one course of thin lines in one direction only, either perpendicular or diagonal, which he afterwards strengthened by retouching them in such parts as were necessary for giving form and prominency, and light and shadow to each object represented. (*Anleitung*, &c. vol. i. p. 173.) His plates possess considerable merit. He engraved several for the collection of the Dresden Gallery, and others after various masters.

[*] Several of his prints bear this date, and several others the date 1467, with the addition of the two letters E and S in Gothic character, and sometimes the letter E only. Strutt gives in his *Dictionary* a remarkable fac simile of this artist. It bears the mark 1461, which Mr. Ottley (*Hist. of Engraving*, p. 604.) conceives to be an alteration of some later date.

[†] Our wonder at the skill of this early burinist diminishes, when we consider that the first Engravers were all or most of them skilful goldsmiths or enamellers, to whom great dexterity of burin was essential long before a single chalcographic print appeared, or was even dreamed of any where: so that from the moment such a discovery as Finiguerra's came to be known there were numbers of expert burinists in the great commercial cities ready to make immediate use of it; and the only circumstance wanted to give the German prints the sort of superiority which they very fairly claim was some mode (which doubtless they adopted) of superior mechanism to the Italian for obtaining copper-plate impressions. M. Bartsch (*Peintre Graveur*, vol. vi. p. 1.) ascribes to the Master of 1466 one hundred and thirteen pieces which he himself has seen, besides eighteen which he mentions afterwards on the authority of other writers.

[‡] See Ottley's *Hist of Engraving*, p. 646. and Bartsch's *Peintre Graveur*, vol. vi. p. 111. Schöngauer's facility of execution, and the equality which pervades his handling, are ascribed to his long previous skill and practice as a goldsmith in engraving ornaments on plate. M. Bartsch enumerates one hundred and sixteen pieces of this artist, and adds an account of seventeen others erroneously ascribed to him. Mr. Ottley has given a very interesting fac simile (*Hist. of Engraving*, p. 646.) of a Madonna by Schöngauer; and Strutt, in a similar spirit of kindness to his reader, has presented us with an imitation of another Madonna by the Master of 1466. Strutt considers these two artists as founders (by means of their numerous imitators and pupils) of two distinct classes in the primitive German School; both which classes, however, died at length away, and became absorbed in the superior claims and attractions of Albert Durer. See ch. v. p. 21. of Strutt's *Essay on the Origin and Progress of Engraving* at the end of vol. i. of his *Dictionary*.

[*] There is an Israhel van Mechen the elder, who is regarded as the father of this artist. He was a painter and goldsmith, but it is doubted by some whether the Engravings imputed to him are from his hand. M. Bartsch's opinion is, that the father and son worked together on the same plates, which when worn were retouched by the younger Mechen. The author of the *Catalogue of an Amateur* observes, that there is no account of the death of the elder Mechen; but the death of the younger took place in 1503, as appears from a document in the British Museum copied from a monumental brass.

The Mechens, though decidedly inferior to many of their contemporaries, and possessing no common portion of Gothic stiffness, have, continues this writer, considerable merit in the execution of many of their pieces. The "Life of the Virgin" may be fairly quoted in support of this. A fac simile is given by Mr. Ottley at p. 660 of his *Hist. of Engraving*, from a specimen of Israhel van Mechen, which ought certainly to have softened the severity of M. Bartsch's criticism. It is a small print representing "Hares roasting the Huntsmen and boiling the Hounds." Among the disciples of Van Mechen, Strutt records *Michael Bogner*, and even *Lucas Jacobs*, called *Lucas Van Leyden*. (Art. 29.) Of Bogner (who flourished in 1487) he records only a small plate representing a coat of arms. He adds to the list several anonymous Engravers, and gives their monograms. (*Essay on the Origin and Progress of Engraving*, p. 21.)

[†] Strutt supposes him a brother of Martin Schön, or Schöngauer. But Martin, as M. Bartsch shows, (*Peintre Graveur*, vol. vi. p. 68.) had no brother of that name. He had four brothers, Gaspar, Paul, Louis, and George, but no Bartholomew.

[‡] *Ce que Strutt avance de deux maîtres de ce nom, d'un aîné et d'un plus jeune, ne semble être qu'une simple conjecture.* (*Peintre Graveur*, vol. vii. p. 245.) Hans Schaufflein, from the similarity of his manner to that of Durer, is considered to have been his pupil.

[§] Mr. Ottley regards the works of *Bocholt* as bearing strong resemblance to those of the Master of 1466; a fact which Strutt acknowledges, and must therefore wave in this instance his distinction of the two classes. Van Bocholt was a native probably of the town of that name in the Bishopric of Munster, where lived also his contemporary Van Mechen above mentioned, of whom, according to M. Bartsch, he was the instructor. Thirty-eight pieces by Bocholt are described in the *Peintre Graveur*, vol. vi. p. 77.

Alert van Hameel,) for whom see the Dutch School; *Wenceslas von Olmutz; Pleydenwurff;* (Art. 29.) *Wolgemuth;* (*Ibid.*) *Matthew Zagel,* (whom some call Martin Zatzinger, others Martin Zinck;) *Mair;* and lastly, an artist whose monogram (the Gothic letters V.G. or V placed within G) Strutt reads *Van Gammerlin.**

The Master of the Anchor.

The *Master of the Anchor,* also so named from his monogram, was of this period. Five pieces from his burin are diligently recorded by M. Bartsch. (*Peintre Graveur,* vol. vi. p. 394.) We might here mention as

Culmbach.

a follower and copyist of Schöngauer *Johan von Culmbach,* a pupil, according to Doppelmayer, of Jacob Welch.† Three of the fourteen prints attributed to Culmbach by M. Bartsch are copied from plates by Schöngauer. But Culmbach is thought to have been an associate in the Art, if not a pupil of the renowned artist with whose name we commence the next paragraph.

Glockenton.

Albert Glockenton also is recorded (*Ibid.* p. 344.) as a copyist of Schöngauer and Engraver of twenty-seven pieces.‡

Chalcography. Durer.

(39.) *Albert Durer,* (see PAINTING, p. 485.) whose celebrity we have already noticed in another branch of Engraving, (Art. 29. p. 790.) was no less conspicuous and influential in that now under consideration. His works seem to have been universally held as models among his contemporaries, and to have superseded all former graphic attempts among his Countrymen. "Great as was the fame of Durer as a painter," says the author of the *Peintre Graveur,* "his productions as an Engraver do him no less honour. His plates show a freedom, delicacy, and facility of burin to which none of his predecessors can make pretension." Indeed, as to neatness and clearness of execution, together with all other mechanical qualifications for the Art, he has never been exceeded; but it has been the regret of all his tasteful admirers, that Durer, with such fertility of invention, such judicious arrangement, such variety and power of expression, (see PAINTING, Art. 279.) should have been deficient in that graceful flow of outline which distinguished his Italian contemporaries, and with which his visit to Italy unfortunately failed to inspire him.*

His pupils and followers.

Durer had, as may be concluded, numerous pupils and followers.†

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* *Wenceslas von Olmutz,* the above-mentioned copyist of Schöngauer, was a goldsmith, and, as his name imports, a citizen of Olmutz in Moravia. He also copied Albert Durer, and sometimes engraved after the designs of Mair. He copied also Israhel van Mechen, or perhaps was copied by him. (*Peintre Graveur,* vol. vi. p. 337.) But from not being a painter, Wenceslas is conceived, by M. Bartsch never to have engraved after his own designs. The great inequality, indeed, both as to composition and design, manifested throughout his Engravings, argues a great number of different designers. His monogram, a W, has sometimes been asserted to stand for Wolgemuth; but M. Bartsch insists upon the improbability that Wolgemuth, from whom Durer learned to engrave, (Art. 29.) would make inferior copies such as these marked W, from the prints of his pupil. Mr. Ottley, however, alluding to a print marked W attributed by M. Bartsch to Wenceslas of Olmutz, and entitled the "Effects of Jealousy," considers it an original production of Wolgemuth. (*Hist. of Engraving,* p. 681.) *Mair,* the fellow-countryman of Wenceslas and a painter, was a native of Landshut in Moravia, and has left twelve Engravings, described in vol. vi. of the *Peintre Graveur. Pleydenwurff,* if he engraved at all, (Art. 29.) was not a Chalcographer · and with regard to such prints as pass under the name of *Martin Zinck,* or *Zagel,* the artist is in fact unknown; but from one of his works, "An Entertainment at Munich," he is imagined to have inhabited that city.

† The name *Welch* is not recognised by M. Bartsch, but the monogram assigned by Strutt to this artist will be found in vol. vi. p. 56. of the *Peintre Graveur,* accompanied by a list of thirty-one copper-plates with this introductory observation: *le maître est remarquable parce qu'il est auteur original. La perte de son nom est à regretter.*

‡ Various other burinists of this ancient period might be added. *Lucas Kranach,* (see Note (W.) at the end of ENGRAVING,) whose copper-plates are extremely few and scarce, born in 1470 at Kronach, in the territory of Bamberg in Franconia, who became painter to the Court of Saxony, and died at Weimar A. D. 1553; *H. B. Grun,* (*Ibid.*) who flourished about 1516, and whose paintings, according to Huber, are numerous in Swisserland and at Strasburg, and adorn the Cathedral of Friburg; *Urse Graf,* (*Ibid.*) die-engraver and goldsmith of Basle; the *Master of the Crab,* (*Peintre Graveur,* vol. vii. p. 527.) Engraver of twenty-four pieces, one of them etched; *Ludwig Krug,* (*Ibid.* p. 535.) or Kruglein, a goldsmith of Nuremburg, supposed to have died there about A. D. 1535. The device *krug,* (a jug,) of which Kruglein is a diminutive, placed between his initials, forms his monogram. Twelve copper-plates are ascribed to him. Of three *Hopfers,* David, or *Daniel,* the first mentioned, (*Ibid.* vol. viii. p 473.) has executed one hundred and thirty-three copper plates, two of them etched in a peculiar manner similar to aquatinta; *Jerome,* the next, (*Ibid.* p. 506.) seventy-seven plates, more than half of them copies from prints by Durer, Lucas Kranach, Marc Antonio, Andr. Mantegna, Agostino Venetiano, &c.; and thirdly, *Lambert,* (*Ibid.* p. 526.) thirty-four plates, chiefly copies from Durer and Ant. de Brescia. Nothing is known of the birth-place, or residence, or exact period of the Hopfers, or how they were connected. Their monogram, a hop, (*hopfer,*) has been mistaken for a candlestick, and they have been called the *Masters of the Candlestick.* Twenty-three plates, thirteen of them etched, have been ascribed to *Justus Amman.* (*Ibid.* vol. ix. p. 351.) Of *Virgilius Solis,* no less than five hundred and fifty-eight copper-plates are recorded, (*Ibid.* p. 242, see also Art. 29.) and among them two pieces etched, representing "The Deluge:" of *Hans Sebald Lautensach* of Nuremburg (*Ibid.* p. 208, also see Art. 29.) fifty-nine copper-plates; and of *Melchior Lorich* (see Note (W.) at the end of ENGRAVING) sixteen.

* Of his Engravings on metal the author of the *Peintre Graveur* particularizes one hundred and eight pieces. Three of them, he remarks, are engraved on plates of tin, two of which have been etched; and four others have been etched on plates of iron. Mr. Ottley, however, is of opinion, that these last-named prints, from one of which he gives a fac simile, are not etchings upon iron, but were executed upon plates of a somewhat softer metal than copper, and with the dry point.

The *Catalogue of an Amateur* includes eleven choice copper-plates by Durer. Among these is the "St. Eustachius," a plate gilt by the Emperor Rodolph in compliment to the artist. "Adam and Eve," A. D. 1504. "Melancholy," A. D. 1514. "Fortune," called, to distinguish it from a smaller print, the "Great Fortune." These three are also selected by M. Bartsch. (*Anleitung,* &c. vol. i. p. 164.) Respecting another remarkable print in the *Catalogue,* entitled the "Prodigal Son," the amateur records a ludicrous mistake of a contemporary Encyclopædist. "In describing the works of Albert Durer under the German School of Engraving in the *Encyclopædia* of Rees, among other prints is noticed, the '*Infant Prodigy,' a kneeling figure in folio:* some pretend that this is a *portrait of Durer himself.* This *Infant Prodigy* is doubtless no other than the 'Prodigal Son' by our artist, so translated by the compiler from the title *l'enfant prodigue* in the Work of Bartsch, or of some French writer."

† The undermentioned artists, followers or pupils of Durer, have been called, from their works being generally of small size, the *Little Masters.* Several of them practised also Engraving on wood. (Art. 29.) *Albert Altdorfer.* (See note (W.) at the end of ENGRAVING.) *Henry Aldegrever,* (Note (U.) *Ibid.*) *nommé par erreur Aldegraaf,* (PAINTING, p. 485.) one of the first who improved the method of representing flesh by dotted lines, (Art. 16.) since brought to beautiful perfection by the French School. *Hans Brosamer,* (see note (W.) at the end of ENGRAVING,) together with these four who completed their studies under Marc Antonio: (Art. 36.) the two *Behams,* uncle and nephew, of whom the former, *Bartholomew,* a painter, has sixty-four copper-plates ascribed to him, (*Peintre Graveur,* vol. viii. p. 81.) and the latter, *Hans Sebald,* (Art. 29.) no less than two hundred and fifty-nine, (vol. viii. p. 112.) thirteen of them etched, and one of them *à l'eau forte sur fer;* George *Pencz,* sometimes called *Gregory Peins,* who was born at Nuremburg about A. D. 1500, and died in 1550 at Breslau, to whom one hundred and twenty-six copper-plates are attributed, to the exclusion of a plate as spurious, (*Ibid.* p. 361.) containing portraits of himself and his wife; also, fourthly, *James Binck,* born about 1490 or 1504, whose

Gradual improvement in chiaroscuro.

Modern School of Germany.

Of the later German burinists we must here take some brief notice. They had now drawn from Italy much improvement in respect of graceful contour. They were next to benefit by the example of their neighbours both in France and in Flanders, amongst whom pictorial effect became at length a peculiar study. The advancement, however, towards a proper introduction of light and shade into engraved works was far from immediate; and chiaroscuro, as to Line Engraving must, perhaps, date its origin from the time when the etching needle was received as a judicious auxiliary to the graver.*

The Kilians.

Sandrart.

But our present business is with simple Chalcography. *Lucas Kilian*, born A. D. 1547, at Augsburg, died there in 1637, after passing many years in Italy, and especially at Venice. His first instructor was his stepfather, Dominic Custos, a printseller and indifferent artist, native of Antwerp, who had established himself at Augsburg. Kilian seems to have formed his style from the works of Egidius Sadeler, (Art. 40.) Henry Goltzius, (*Ib.*) and Muller, pupil of Goltzius. He may be called the patriarch of a family of artists; for an account of whom we refer our readers to more copious biographical sources. *Wolf-gang Kilian*, his brother, we may pronounce neater in execution, but both are thought deficient in accuracy.† *Jacob Sandrart*, who flourished at Nuremburg in 1660, nephew of Joachim the celebrated Biographer, engraved in a neat clear style a number of portraits, and among them that of his uncle.

Schmidt.

George Frederic Schmidt, born in 1712 at Berlin, (where he died in 1775,) after a course of academical application until his twenty-fourth year in that Capital, had the further advantage of studying under the celebrated burinist of that day, Nic. de Larmessin, at Paris, where he so entirely profited by the instructions of that able master as to be admitted, in 1742, (although a Protestant, and living in very bigoted times,) into the French Academy of Arts, by an express order from the King of France. He again visited Berlin, and was there honoured, in 1757, by a request from the Empress (Elizabeth) of Russia, to visit Petersburg and engrave her portrait. This commission he executed with admirable skill, in addition to the number of excellent portraits already from his burin. His last works were beautiful etchings *à la Rembrandt.** Contemporary with Schmidt was *John George Wille*, who, from residing chiefly at Paris, has been frequently classed among the French Engravers. Born at Konigsburg A. D. 1715, he originally followed the business of an armourer, and came to Paris in 1736, where, at his arrival, he was so poor as to be glad to accept some miserable situation at a watchmaker's. This, however, he soon quitted for his ordinary occupation at a gunsmith's. But his passion for Engraving was not to be restrained by poverty: he at length devoted himself wholly to the Art, and was first employed by Odieuvre, the printseller, to engrave portraits. Schmidt, with whom he became formerly acquainted at Strasburg on his way to Paris, and Hyacinthe Rigaud, the great portrait-painter, who assisted him with his purse and advice, were his fast friends. His powers of graphic representation were adapted with peculiar skill to the appropriate texture of objects, and his burin has been most happily illustrative of the highly finished paintings of Douw, Mieris, Metzu, Netcher, and Terburg. These talents, together with those of his friend Schmidt, and of John Martin Preisler (Schmidt's pupil) of Nuremburg, rendered Paris at one time the finest graphic School in Europe. He died at Paris in 1808. His instructions and example produced several excellent followers.†

J. G. Wille

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birthplace is by some fixed at Nuremburg, and by others (from his inscribing himself Coloniensis) at Cologne. (See note (U.) at the end of ENGRAVING.) Residence at Rome has sometimes obtained for Binck, together with the other German pupils of Marc Antonio, a place in the Italian School. M. Bartsch, however, conceives that Binck might never have been at Rome nor under Marc Antonio. (*Peintre Graveur*, vol. viii. p. 256.) He painted for some time at Konigsburg, was in the service of Albert of Prussia, A. D. 1551, and died at Konigsburg about A. D. 1560. The great inequality among the various works bearing the monogram of Binck, makes it difficult to ascribe them to one and the same hand. Among the ninety-seven copper-plates ascribed to him in the *Peintre Graveur* are copies from Albert Durer, from the Behams, and from M. Antonio.

Some authors extend the number of these *Little Masters* by adding many artists who were not Germans nor pupils of Durer.

* "While the etching point," says Strutt, "remained in the hands of the painters only, no great improvement could be supposed to take place. Their attention was necessarily turned to objects of greater importance, and etching was considered in general by them as an amusement. By Engravers, too, the point was too much neglected. They seem to have regarded it as a thing of small consequence till such time as Girard Audran, by uniting it with the graver, produced those performances which have done his Country honour." Strutt's *Essay*, p. 10.

† M. Bartsch remarks of the portraits engraved by *Lucas*, that they are characterised by beautiful simplicity, and that his works, chiefly portraits, show boldness and facility. The plates of Lucas amount to two hundred and thirty.

* Of *Schmidt*, it is observed by Watelet, that he not only guided his burin with singular ease and grace, but handled his etching needle also with all the lightness and playfulness of a Castiglione or a Rembrandt. No artist of modern date has approached nearer to Rembrandt, and this approximation he accomplished, says M. Bartsch, not so much by means of Rembrandt's thickly repeated strokes of the dry needle, in order to conceal each separate stroke of his point, as by the apparent disorder under which, uniting every style of handling, he hides from obvious view the source of so much spirited and tasteful effect. A force of chiaroscuro is thus obtained superior to that of any other artist of the same class. His works consist of two hundred and seventy-three plates.

† Among the distinguished pupils of Wille was *Jacob Schmutzer*, born at Vienna A. D. 1733. He belonged to a family of Engravers. His two uncles, *Joseph* and *John Adam Schmutzer*, together with his father *Andrew*, were all more or less handlers of the graving tool, the use of which descended to them likewise from their parent, the son of a General in the Imperial service. The General, ruined by the vicissitudes of war, left that son no other inheritance but the faculty of contriving to live. The heir to this faculty, however, found means of subsistence, by having learned to engrave in iron or steel the ornamental parts of locks, swords, and fire-arms. To the same occupation all his above-named progeny were reared, and to this has been attributed their great facility as burinists. Jacob Schmutzer, at his return to Vienna, (he died there in 1806,) was appointed a Director of the Academy established by the Empress Maria Theresa in that Capital. Here he superintended the education of numerous students, and became as great in his native metropolis as Wille his master had been at Paris. Jacob Schmutzer's free yet judicious handling and firm outline well suited him for an Engraver of Rubens, whose works he chiefly selected. The broad effects of chiaroscuro and bold tournure of the figures characterising that master were transferred with congenial spirit from the canvass of Rubens to the copper-plate of Schmutzer. Had he chosen Raffaelle, whose noble simplicity, observes M. Bartsch, his mind was not formed to appreciate, he would have failed. Another eminent pupil of Wille is *Johan Gotthardt Muller*, born A. D. 1747 at Bernhausen, in the Duchy of Wirtemburg. The Duke became his patron, and sent him at the age of twenty-three to complete his studies at Paris, where, in 1776, he was admitted a member of the French Academy. He returned soon after to Stutgard, and became Professor of Design in the Ducal Academy there. He died in 1814. His works, which in History and in Portrait are equally admirable, evince excellent drawing and distribution of chiaroscuro, together with the neatest execution and most judicious handling. A full length of Louis XVI. of France, after Duplessis, is among the most esteemed and perfect of his portraits. To this list of modern burinists in Germany we may subjoin from the *Anleitung* of M. Bartsch the name of another pupil of Wille. *Sebastian Ignaz Klauber*, born at Augsburg in 1754. He had resided and studied

Dutch and Flemish Schools with the burin only.

(40.) The DUTCH and FLEMISH masters in simple Chalcography next claim and deserve attention. Their perseverance and their success in this peculiar department of the Art place them among the best examples for the imitation of all future artists. But, probably, no period will ever again occur so prolific in able burinists as the latter half of the XVIth and first half of the XVIIth Century. Of these graphic generations of men, the Engravers of the Low Countries are unquestionably among the ablest and most numerous. Leyden, Amsterdam, Brussels, Utrecht, and Antwerp, but especially the last-mentioned city, poured forth reams of copper-plate, and from the hands of beautiful contributors. From Leyden came *Lucas Jacobs*, the father of Flemish Art, (Art. 29. and PAINTING, p. 480.) and *longo temporis intervallo*, *John Saenredam*.* From Amsterdam and Haerlem, the School of Henry Goltzius, came the *Mullers*, the *Wierinxes*, and the *Visschers*.† From Utrecht the *Count de Goudt*, the

Lucas van Leyden.

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at Rome a considerable time before his visit to Paris, where he became a member of the Academy, and received the title of Engraver to the King. He was living in 1806 at Petersburg. His print after Polemberg, *Le petit écolier de Haerlem*, and another of the "Saviour," after Stella, would do honour to the burin of Wille himself.

* Lucas Jacobs, the contemporary of Durer and of Marc Antonio, is better known by the name of Lucas van Leyden, the city in which he was born, A. D. 1494. His life, like Raffaelle's, was short, and did not reach forty, but like that of Raffaelle (who was his junior by eleven years) comprised enough occupation for many lives. The *Peintre Graveur* records (vol. viii. p. 339.) one hundred and seventy-four pieces of this master, three of them etchings, and two others partly etched and partly completed with the graver. Other etchings by some *inconnu* in the style of Lucas are mentioned. All his works are from designs of his own, many of which are scriptural subjects, commencing with a series of six from the creation to the murder of Abel. Five others represent the History of Joseph, and a set of fourteen the History and Passion of our Lord. A repetition of the latter subject in a series of nine prints was designed for painting on glass. According to Vasari, Albert Durer was so much struck by one of Lucas's works, that as an effort in competition with it he designed and engraved the print called his "Horse of Death." Durer came to visit his competitor at Leyden, where, in token of their mutual esteem and amity, they painted each other on the same canvass. The excessive application of Lucas so impaired his health, that for the last six years of life he scarcely left his bed, and his mind, which in his early days had been gay and cheerful, lost all its natural tone, and was haunted by suspicions of poison. So that this declining period was a melancholy contrast to former gaiety, when in a handsome vessel of his own he made a voyage to the Netherlands, and feasted all the Flemish painters, with his friend John de Mabuse, attired in cloth of gold, at their head, on four magnificent occasions, at Middleburg, at Ghent, at Mecklin, and at Antwerp, expending sixty florins for each repast.

From the burin of *John Saenredam*, born at Leyden, about A. D. 1570, a catalogue is given in the *Peintre Graveur* (vol. iii. p. 219.) of one hundred and twenty-three pieces, of which only twelve are after his own designs, and the rest after P. Veronese, M. A. Caravaggio. Abr. Bloemaert, Lucas van Leyden, &c. He was a pupil of Henry Goltzius hereafter mentioned.

† *Henry Goltz* or *Goltzius* was born A. D. 1558, at Mulbrecht in the Duchy of Julien. On his return from Italy, where he studied and engraved under some of the best early masters, he settled in the neighbourhood of Amsterdam at Haerlem. At the age of forty-two he commenced Painting. (PAINTING, p. 481.) His family had already become illustrious in the person of *Hubert*, the learned antiquary, entitled Painter and Historian to Philip II. of Spain, and no inconsiderable Engraver. But Henry, though not equally profound, was an artist of more genius than Hubert. His ambition was to attain the "sublime" by the study of Michael Angelo and Raffaelle. He was, however, betrayed, like other imitators of Angelo, into the "*bombastiu.*" But he was a perfect master of anatomy: he drew the extremities of the figure with irreproachable precision, and his burin, notwithstanding the affectation we allude to, charms every eye by the beauty and freedom of its execution. He had sufficient command of this instrument to be able, by the labour of a few months in 1593 and 1594, to complete six pieces in such perfect imitation of the old masters, Durer, Lucas van Leyden, &c. (hence called his *master-pieces*,) that he passed his counterfeits for some time as originals, and enjoyed ever afterwards a signal triumph over such virtuosi of his time as were loud in proclaiming the universal degeneracy of the Art, and accused him and others of introducing a new style of Engraving, only through inability to match the old. M. Bartsch enumerates two hundred and twenty-five copper-plates engraved by Henry Goltzius from his own designs, and seventy-seven from designs by others. His pupils *Saenredam* (for whom see last Note) and *Matham* sometimes resembled him so closely that it is difficult to assign each his due. By *James Matham*, who was the son-in-law as well as pupil of Goltzius, we have on record three hundred and fifteen plates. Of these about two hundred and forty are spoken of as being certainly his: the remainder (among which are four *à l'eau forte*) have been attributed to him, or had been engraved under his directions. (*Peintre Graveur*, vol. iii. p. 193.) Another scholar of Henry Goltzius was *John Muller*, born at Amsterdam about A. D. 1570, to whom are assigned eighty-seven pieces. (*Ibid.* p. 265.) He had the art of economizing the strokes of his graver so as seldom to exceed two courses of lines. *On est étonné*, says M. L'Evêque, *de voir avec quelle adresse il oblige une méme taille à lui servir de première ou de seconde, pour rendre une figure entière. Il fait très-rarement usage d'une troisième taille, et ce que n'est jamais que dans une partie de peu d'étendue et qu'il a voulu sacrifier. Avec cette savante économie on ne lui peut reprocher ni monotonie dans l'effet général, ni uniformité dans la manœuvre.* (*Encyclopédie Méthodique*, Beaux Arts, p. 370.) *Herman Muller*, a supposed relation of this artist, was likewise his fellow-student, partaking more of the laboured style of that period of Flemish Art, but with a tolerably correct outline. He engraved several plates at Antwerp in conjunction with Cornelius Cort (Art. 37.) for Jerome Cock, and also in conjunction with the Galles, the Sadelers, and others, several subjects from the Bible after John Stradan, Martin de Vos, and other masters. Among the disciples of Goltzius we must not omit *James de Gheyn*, (called the elder, to distinguish him from an Engraver of the same name,) born at Antwerp in 1565. His prints, which show great command of the graver, are in high esteem.

The Mullers, Wierinxes, and Visschers. Goudt.

Amsterdam gave birth to three brothers of the family of *Wieriz* or *Wierinx*, all of them designers and Engravers. *John*, the eldest, born in 1550, must have formed his style upon that of Albert Durer, whose works he studied and followed with the servile minuteness of the most implicit copyist. He engraved also from his own designs, which betray poverty of invention. But his prints are much sought by the curious: his execution is neat and finished; and his drawing generally corect. *Jerome*, the next brother, born A. D. 1552, was probably the pupil of John, whose prints would not be known from Jerome's but for the Engraver's mark. The same neatness, the same quaintness, the same undeviating formality, will be seen in both. The youngest brother *Anthony*, born about two years after Jerome, executed some small plates in the style of his brothers; but his larger productions show greater freedom and more facility. The subjects for Engraving undertaken by the three Wierinxes, who frequently worked in conjunction, are in the departments both of Portrait and of History.

Cornelius Visscher was born at Haerlem about 1610. His instructor in Engraving was *Peter Soutman* of the same birth-place, born about the year 1590, a Dutch painter, and pupil of Rubens. Visscher, however, rejected the style of his master Soutman, and adopted one for himself, in which he became unrivalled. Besides tasteful and correct drawing, his works, especially those from his own designs, are replete with originality and inventive genius. In his plates, indeed, after designs of the Italian and Flemish masters, and in particular after Rubens, he is confessedly inferior to the brilliant triumvirate, consisting of Vorsterman, Bolswert, and Pontius. No artist, we may here add, has ever surpassed Visscher in the talent of harmonising the operations of the graver with that of the point to which he occasionally resorted. His younger brother *Jan* or John, who flourished about A. D. 1650, adopted the point more frequently. He also was an admirable artist, though without the extensive talent of Cornelius, and sometimes without accurate delineation of the figure. *Cornelius van Delen* of Antwerp, an Engraver in History and Portrait, is mentioned as a disciple of Cornelius Visscher. But a much more eminent Dutch artist of the Schools of the Visschers was *Abraham Blooteling*, born at Amsterdam in 1634. He lived for two or three years in England. His chief works, however, are not from the graver only, but are either etchings or in mezzotinto. (Art. 61.)

Besides Cornelius Visscher, there was another scholar of Soutman also among the ablest burinists of that day, namely, *Jonas*

Bloemaert, and Family of De Passe. The Galles, the Vostermans, the Bolswerts, Paul Pontius and others.

family of *De Passe*, and *Cornelius Bloemaert*.[*] From Brussels the *Sadelers*,[†] and from Antwerp their scholars. From Antwerp also came *De Gheyn*, a fellow-student in the School of Goltzius, with Saenredam, already named; and from Antwerp the *Galles*, the *Vostermans*, the *Bolswerts*, together with *Paul Pontius*, and a host of pupils,[‡]

Snyderhoef, born at Leyden A. D. 1600. He pursued the style which his master had adopted, but with a delicacy and finish peculiarly his own. Together with great neatness he combined great force of colour, and to repeat the eulogium of Strutt, he harmonized the light with the shadows so as to produce a fine effect. Strutt complains, however, that his drawing of the figure is sometimes faulty, and M. Bartsch, that his handling is not always clean, but the latter critic distinguishes him for extraordinary warmth, truth, and power of expression.

[*] The family of *De Passe* has given celebrity to Utrecht their native city. *Crispin de Passe* the elder, born there about A. D. 1560, is said to have learned Engraving from *Dirk* (Theodore) *van Cuernhert* of Amsterdam, the instructor of Henry Goltzius, but more celebrated as a controversialist than as an Engraver. Like Cuernhert, De Passe was a man of letters, but was far beyond him both as an artist and as a patron of Art. He published at his own expense Holland's *Horologia*, and in his latter days a Drawing-book of his own for the advancement of students, printed in Italian, French, and Dutch, at Amsterdam, in 1643, after his return from England. This Work, entitled *Della Luce del Depingere e Designare*, is prefaced with some account of his life and studies, and mentions Rubens, Blomaert, and other distinguished contemporaries, as his friends and encouragers. It contains the experience of more than seventy years passed from earliest youth in assiduous cultivation of the Art; treats of Geometry and Perspective; of the proportions of the human figure; of studying by lamplight; of adjusting the lay figure for draperies; and of comparative anatomy for drawing quadrupeds, birds, and fishes. The prints of this artist, which are very numerous, possess clear, neat, and original execution, and his drawing is correct, but sometimes formal, and sometimes tending to the bulky forms of Rubens. His portraits have great merit, and, together with those by his three sons, *Crispin*, *William*, and *Simon*, as well as by his daughter *Magdalen*, are interesting to us not only as works of Art, but in their connection with an important era in European, and particularly English History. William, born at Utrecht about 1590, and Simon, the youngest son, were the most remarkable of the four. Magdalen de Passe engraved after Elsheimer, in imitation of (but in a style inferior to) Count Goudt.

This distinguished gentleman and artist of Utrecht, and of a noble family of Holland, *Henry Count de Goudt*, was born in 1685. He went early to Rome to study in the Academy, where he became the associate and friend of the celebrated but unfortunate Painter *Elsheimer*, by whose instructions he profited, and whose pictures he liberally purchased. He thus enjoyed the twofold gratification of relieving his preceptor from indigence, and of obtaining those originals after which he employed his burin, and has so happily imitated the delicacy and peculiar finish of his industrious and ingenious master. The style of Goudt was quite his own, but was perhaps the best possible for expressing the remarkable chiaroscuro of Elsheimer. It was not by the usual mode of deepening and strengthening the strokes, but by delicately crossing and recrossing them in the shadows that he accomplished his purpose.

Another native of Utrecht was *Cornelius Bloemaert*, born there in 1631, who died at Rome in 1680. He belonged to a family of artists. *Abraham*, his father, a painter of eminence as a colourist, and whose prints in chiaroscuro, by the joint use of wood blocks and copper-plates, (last Note to Art. 12.) we shall have occasion to mention, had four sons all of them Engravers. But *Cornelius*, the youngest, was the only distinguished burinist among them. The softness of his transitions from light to shadow, together with the truth and beauty of his aerial perspective, by which he suited his tints in delicate gradation and infinite variety to the different distances of any required representation, have never been exceeded. Before his time harmony was often disregarded; lights were left indiscriminately clear; and in general a patched and spotty effect was the natural consequence. But Bloemaert reformed these errors, and may be regarded as the founder of that style which was afterwards to distinguish the great masters of the French School, Audran, Baudet, Picart, and Poilly. M. Bartsch complains of Bloemaert that a general weakness of effect exists in his Engravings, from the absence of powerful shadows, a deficiency which is most observable in his draperies, and which arises from a sameness in the direction of his hatchings throughout the work. He says of him, however, that although his burin is generally somewhat cold, yet in working after any able colourist, he was quite competent to produce sufficient warmth of effect, such as we see exemplified in the most celebrated of his plates, "The Raising of Tabitha," after Guercino. Among the pupils, followers, and associates in Art of Cornelius Bloemaert were *Theodore Matham*, son of James mentioned in our last Note, *Michael Natalis*, *Reynier de Persyn*, and others. These engraved together at Rome the Statues of the Giustiniani Gallery. A Flemish pupil of Bloemaert, and also of Spierre, (for whom see the French School; Art. 41.) was *Peter Clouet*, born at Antwerp in 1606. On his return to settle in his native city he engraved many subjects in the style of (but unequal to) Pontius. His example was followed by *Albert* his nephew.

[†] The progenitor of this family was an ornamental workman at Brussels, who engraved steel and iron to be afterwards inlaid with gold or silver. His sons, *John* and *Raphael Sadeler*, born at Brussels in 1550 and 1555, were brought up to their father's business, and their mechanical education may account for the numerous plates which their facility of handling enabled them to execute: although John, the elder son, was nearly twenty years of age before he commenced Engraving on copper. The success of John induced Raphael to become his pupil, and the two brothers travelled through Germany together for improvement, and to Venice, where they settled, and where they died. Their drawing of the human figure is generally correct, and the extremities are carefully marked. The expression of John's heads has been much admired.

It is *Egidius Sadeler*, however, a nephew of the foregoing, born at Antwerp in 1570, that ranks among the best of Flemish burinists. After being well grounded in the principles of Design, he acquired, with the assistance of his above-named relatives, such command of the graver as even to surpass his instructors. His execution is remarked to be as dexterous and happy in works requiring the utmost neatness and delicacy as in others that demand strength and boldness. Portrait, Landscape, and History exercised alternately the powers of this gifted and inexhaustible artist. Some plates are from his own designs, which are highly valued, especially his portraits. The Emperor Rodolph II. invited him to Prague, where he received the substantial honour of a pension, and enjoyed the favour of the two succeeding monarchs, Matthias and Ferdinand II., and where he died in 1629. *Peter Furnius*, resident at Antwerp, a contemporary of the Galles and Sadelers, and who furnished them with several designs, may here be noticed.

[‡] *Philip Galle*, native of Haerlem, born A. D. 1537, settled at Antwerp, and with his sons *Theodore* and *Cornelius* became eminent in Engraving; but particularly Cornelius. The latter greatly surpassed his father and brother, and had acquired at Rome, where he resided several years, admirable correctness of design, united to freedom and facility of execution. At Antwerp he finally settled and carried on the business of a printseller. His son, called *Cornelius the younger*, born A. D. 1600, does not appear to have had the advantage of studying in Italy, which may account for an inferior degree of correctness in his drawing to that of his father and uncle. His portraits, chiefly from Vandyke, are among the best of his works.

Lucas Vorstermann, born at Antwerp A. D. 1580, studied painting in the great School of Rubens, by whose advice he exchanged the palette for the graving tool. Among the several able artists who profited by the assistance of that judicious preceptor, no Engraver was more successful than Vorstermann. A print in his hands became a picture, for he was more attentive to general effect and intelligent discrimination of objects than to neatness and regularity of execution. At the same time he guided his burin with the happiest facility; his outlines are perfect, his heads full of expression; and his graphic transcripts of Rubens are faithful, spirited, and worthy of his master. He was called the *elder* Vorstermann, to distinguish him from another *Lucas*, his son, who, with all the benefit of paternal instruction, never rose above mediocrity.

Two brothers, named *Bolswert* or *Bolsuerd*, from the place of their nativity in Friesland, were contemporaries of the elder Lucas, and removed to settle at Antwerp as printsellers and Engravers. *Adam Boetius a Bolswert*, born about 1589, is remarkable for the finish and fullness of colour with which he engraved from Rubens. *Scheltius a Bolswert*, however, the other brother, (about six years younger,) was decidedly superior. He was the intimate friend of Rubens, who not unfrequently retouched his proofs, in the progress of an Engraving, with chalk or with pencil.

Paul Pontius, or *du Pont*, another artist who engraved under the superintending eye of Rubens, was born at Antwerp about A. D

C. Vermeulen.

Cornelius Vermeulen, is placed by M. Bartsch, (*Anleitung*, *&c.* vol. i. p. 187.) perhaps from the circumstance of his having worked for French booksellers, or of having lived some time in France, among the French Engravers; but he resided principally in his native city Antwerp, where he died A. D. 1702, at the age of fifty-eight. His portraits are much admired, and some of them engraved for Isaac Larrey's *History of England*, 4to. 1697, have given its chief value to that book; but in historical compositions, from his defective drawing of the figure, he was not successful. M. Bartsch concludes his list of modern burinists of Holland (*Ibid.* vol. i. p. 182.) with the name of *Jacob*, son of Arnold *Houbraken*, a Painter and Biographer of Dutch artists. Jacob was born at Dort A. D. 1698, and died there in 1780. His instructor in the Chalcographic Art is not known; but he probably was most indebted to his own genius. He evidently studied Edelinck and Duvet and the French School. (Art. 41.) He is considered not inferior in delicacy to Duvet, and sometimes exceeds him in boldness of handling and strength of colour. The glossiness and lightness with which in his portraits he represents the human hair are inimitable; and by introducing rough lines among his draperies and accessories in bold contrast with the delicate tints of his carnations, "he produces," says M. Bartsch, "a most artist-like effect:" in proof of which we are referred to the "Four Burgomasters of Amsterdam," after J. Wandelaar.*

Jacob Houbraken.

The reader will perceive that our limits imperatively oblige us to pass over numerous minor artists, since we have been compelled to refer him for a short account of even the highest class to our Notes, in which the smallness of the type enables us to comprise a few remarks on each within a smaller portion of our pages.

French School in simple Chalcography.

(41.) In FRANCE, the early period of this Art is clouded, as might be supposed, with uncertainty and barbarism. We have already noticed the earliest attempts in that Country at Xylography, which probably were made by German emigrants or settlers. (Art. 29. and Note (W.) at the end of ENGRAVING.) The same may be said of early prints in France from metal and copper-plate, some of which, such as the plates for a book published at Lyons, A. D. 1488, *An Emigration beyond Sea to the Holy Land*, (compiled from the Itinerary of Bernard de Breydenbach,) are copied on metal from the wood-cuts of the original Work. The original had appeared some years before at Mentz.*

Chalcography.

Duvet, the Master of the Unicorn.

The first Frenchman whom we can positively name in the French School of Chalcography is *Jean Duvet*, called the *Master of the Unicorn*, not from the cipher he used, but from his frequent introduction of a unicorn into his designs. He was a goldsmith, born A. D. 1485 at Langres, who continued to exercise his graver, as appears from his dates, till he attained the age of seventy-nine. His style, however, did not require (according to M. Bartsch, who describes forty-five pieces) a stronger eye-sight than was compatible with that advanced term of life.

De Laulne, N. Garnier, S. Bernard, Voeiriot, Boivin, and P. Thomassin.

Our next names, with which we proceed to fill up the following century, are *Etienne de Laulne*, *Noel Garnier*, *Solomon Bernard*, *Voeiriot*, *Boivin*, and *Philippe Thomassin*.† The last of these was the instructor at Rome of Jaques Callot, whose judicious combination of the point with the graver we shall hereafter notice.

L. Gaultier.

Leonard Gaultier, or Galter, who flourished about A. D. 1610, imitated Crispin de Passe and the Wierinxes. (Art. 40.) His designs were chiefly his own, but he sometimes engraved after Raffaelle and others. His burin has the fault of stiffness, but the precision and the neatness are not less remarkable than the surprising number of his works, amounting in the collection of the Abbé de Marolles to upwards of eight hundred. The name of *Audran* is also famous in the annals of French Chalcography. We do not here mean to include Girard, who claims a place hereafter as uniting the point with

Claude and Charles Audran.

1596. He was the pupil of Lucas Vorstermann the elder, but derived his chief improvement from their common friend and instructor. His hand, indeed, seems to have obeyed no other mind but that of Rubens; and his portraits, after Vandyke, are no less estimable.

In the above triumvirate, as it is sometimes called, of the Flemish School, the peculiar excellence of Pontius has been pronounced to consist in pictorial force and general effect: that of Scheltius a Bolswert in facility and expression: that of Vorstermann in delicacy and variety. Some Flemish followers and pupils of Pontius may here be mentioned. *Nicholas Lauwers*, a historical and portrait Engraver, was born at Leuze near Tournay about A. D. 1620. He studied at Antwerp, and has engraved after various masters, but his best prints are after Rubens, in the style of Paul Pontius, whose manner he successfully followed, but followed of course at some distance behind his master. *Nicholas Ryckman*, born also about A. D. 1620 at Antwerp, adhered to the same School with a neat but formal and stiff burin, and in general an incorrect outline. *Conrad Lauwers* executed in the same style as his above-named brother Nicholas, but not so successfully, several plates after the Flemish masters. *Alexander Voet*, born 1613 at Antwerp, is another supposed pupil of Pontius, but drew incorrectly. *Matthew Borrekens*, born about A. D. 1615 in the same city, also imitated Pontius, but not successfully. He was much employed by print-sellers in copying the plates of eminent Engravers.

* The *Catalogue of an Amateur*, to which we have frequently referred, observes, concerning the great Work of Houbraken, entitled *Portraits of Illustrious Men*, that the ornaments which surround the portraits were designed, as well as chiefly engraved, by Gravelot; and adds a belief that the greater part of the portraits, as well as their accessories, were sent by Knapton to Houbraken in a very forward state, the work of Gravelot. This is the case, for instance, with the beautiful plate of Anne Boleyn, which the writer ("the Amateur") himself possesses in different states. The first, though very forward, has none of the work of Houbraken.]

* The plates only differ from their wooden original in being more incorrectly drawn, and in the addition of some vessels and figures to the respective views of Oriental ports and cities described. The execution is neat but barbarously stiff and hard.

† *Etienne de Laulne* was born at Orleans in 1520, and died in 1595 at Strasburg, where he is supposed to have learned the Art, but from what instructor is not known. His plates, amounting to three hundred and ninety, are chiefly from his own designs. Some are very excellent copies from Marc Antonio. His designs are often well imagined. but his drawing of the figure is defective, and his chiaroscuro, like that of his contemporaries, almost nothing. *Not* or *Noel Garnier*, already noticed as an Engraver on wood, (Art. 29.) was born about 1520. He has been called, without any authority, the first introducer of the burin into France. He was probably a goldsmith, and has engraved in the rudest style possible forty-eight plates, representing Arts, Sciences, and Trades; together with some grotesque ornaments, and an alphabet of capital letters, eleven of which we find accurately described in the *Catalogue of an Amateur*. *Solomon Bernard*, called *le petit Bernard*, from the small size of his works, was a native of Lyons, and contemporary with the preceding artist. He was a pupil of Jean Cousin, a father of the French School, (see PAINTING, p. 490.) and he transferred both to wood and to copper many tasteful designs, which show much improvement in the Art.

Pierre Voeiriot, or *Woeiriot*, was another goldsmith, born in 1525, whom we have also named among our Xylographers. (Art. 29. p. 791.) His works on copper are not discreditable for that period. The copper-plates of his contemporary, *René Boivin*, who likewise divided his time between wood and metal, have been remarked to bear some small resemblance in their style to Cornelius Cort, (Art. 36.) of whom *Philippe Thomassin*, born at Troyes in Champagne, A. D. 1536, was a disciple, and engraved at least two hundred plates. The style of Thomassin is pronounced by Strutt to be clear and firm, but stiff and mannered, and with a total absence of effect.

the burin, but we must notice *Claude* his father, and *Charles* his uncle, from each of whom he received instruction, and who, as burinists,[*] emulated the style of Cornelius Bloemaert. (Art. 40.) P. Lombart, the Davids, M. Lasne, and J. Blondeau *Pierre Lombart*, the *Davids*, and *Michel Lasne* are of this period.[†] *Jacques Blondeau*, of later date, engraved, in conjunction with Bloemaert, Spierre, Clouet, &c., a series of plates from the Pictures by Pietro da Cortona in the Palazzo Pitti at Florence. The Prints of Blondeau are cold and silvery, and without much effect. His drawing too was De la Haye. defective. *Charles de la Haye*, who assisted in the same Work, was a better draughtsman but a worse burinist.

Family of De Poilly, &c. The XVIIth Century was prolific in French burinists of the highest class. *Mellan* and the family of *De Poilly*[‡] were followed, the former by *Nanteuil*, *Frosne*, *Thiboust*, &c., and the latter by *Pilau* of Antwerp, *Chateau*, *Nollin*, *Scotin*, *Rouillet*, *Spierre*, and several others.[*]

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[*] *Charles Audran*, born at Paris in 1594, was the younger and more eminent of the brothers. He studied at Rome, and seems to have been inclined to adopt the manner of Lucas Kilian and the Sadelers. (Art. 39. 40.) The Abbé Marolles, who gives him high praise, ascribes to him one hundred and thirty pieces. He lived to the age of eighty, and saw the fame of his two nephews and pupils Germain and Gerard arrive at full maturity.

An early artist, whose name is unknown, remarkable for delicate and elaborate finishing, and called from his monogram *le maître à l'écrévisse*, or the *Master of the Crab*, may here be noticed. The *Peintre Graveur* (vol. vii. p. 527.) records four and twenty pieces from his graver, chiefly sacred subjects. *Thomas de Leu*, born at Paris about 1570, may be also quoted for neatness of execution.

[†] *Pierre Lombard* or *Lombart* was born at Paris about A. D. 1612. From whom he learned to engrave is not known, but he was a scholar of Simon Vouet. (PAINTING, p. 490.) The lines of his graver are neat but laboured, and his style is without much taste. "His dark shadows," in the words of Strutt, "want force and boldness, and his lights are too evenly covered, which gives a flatness to his figures and prevents their being relieved from the background with any striking effect." This fault pervades even his twelve celebrated half length portraits called the "Countesses of Vandyke," which he engraved in England, having repaired to this Country shortly after the Restoration, where his chief employment was for the booksellers. For this reason some have placed him among English Engravers.

The two brothers, named *David*, with the Christian names of *Charles* and *Hieronymus*, or *Jerome*, were born at Paris about A. D. 1605. Both pursued the same style, a style formed upon numerous preceding models; but Charles, whose works are in much estimation, was the better Engraver. His outline of the figure is in a great degree correct, but he overcharges it by marking his muscles too powerfully. "His lights," says Strutt, "are scattered and too equally powerful, like those of his contemporary artists," and his work is rendered disagreeable by "crossing his second strokes too squarely upon the first."

Michel Lasne was a dexterous Parisian follower of Bloemaert (Art. 40.) and Villamena. (Art. 37.) *Etienne Baudet*, his contemporary of Blois, quitted the manner of Bloemaert, and became eminent for uniting the point with the burin in the style of J. B. Poilly. (Art. 56.)

[‡] *Claude Mellan* was born at Abbeville in 1601, and died 1688, at Paris, where he received his first instruction. He visited Rome at the age of only sixteen, and meeting with his Countryman, Simon Vouet, (PAINTING, p. 490.) he studied Painting under that master, but quitted Painting for Engraving, to which, for the remainder of a long life, he applied himself; working chiefly from his own designs. His plates, engraved at Rome, are numerous and much valued: particularly those after "busts and statues in the Giustiniani Gallery;" a portrait of the "Marquis Giustiniani;" and another of "Pope Urban VIII." He is said by Florent le Comte to have declined an invitation from Charles II. to visit England: preferring to remain in his own Country, and under the patronage of his own King, who assigned him apartments in the Louvre, where he died universally honoured and beloved at the age of eighty-seven. His Prints, engraved at Rome, are executed in the usual manner, but he afterwards adopted the novelty for which his name has been notorious, of representing objects by single ranges of lines, instead of crossing the strokes. His shadows are expressed by the same strokes being made stronger and brought nearer to each other. The effect produced by this method of Engraving is soft and clear. In single figures and small subjects he succeeded very happily: but in large compositions where great depth of shadow is required he has failed in proportion to the force of colour wanted.

His "Face of Christ," or "Sudarium of St. Veronica," is executed entirely by a single spiral line, begun at the extremity of the nose and continued over the whole face and background without a single break. The subject is an old Romish legend, that a handkerchief was presented to the Saviour on his way to Calvary by the Saint Veronica, which, after having wiped his face, he returned to her with a representation of his countenance miraculously impressed upon it. It is difficult to say which of the two things is the more whimsical: the legendary subject, or Mellan's graphic treatment of it. We cannot help associating this performance with those *wonders of art* in which a frontispiece engraved by John Sturt of London represents the head of George I., composed of lines written so small that the reader uses a microscope and finds them to contain the Lord's Prayer, the Commandments, the Prayers for the King and Royal family, and the twenty-first Psalm! Or, to go from follies of the eye, to those of the ear, our thoughts wander irresistibly to a deservedly celebrated Violinist and Musician of our times, who sometimes catches at ignorant applause by tricks, lucrative enough certainly, but unworthy of his taste and skill. Mellan is the Paganini of Engravers. (See Note (G.) at the end of ENGRAVING.) According to Le Comte the works of Mellan amount to three hundred and forty-two pieces.

Mellan left no son to inherit his eccentricities or his ability; but from Abbeville, his native town, arose the family of *De Poilly*, of which two brothers, *François* and *Nicolas*, were excellent burinists. From their father, a goldsmith, they early acquired the mechanical facility for which the Art in the XVIIth Century is so much indebted to that occupation. François, the elder brother, is one of the most skilful handlers of the graver that France has ever produced. Boldness, firmness, clearness, brilliancy, and accurate finishing characterise his prints, which amount, according to M. Bartsch's *Guide to Engraving*, (*Anleitung*, *&c.* vol. i. p. 184.) to two hundred and twenty-six. But he is monotonous, and betrays a peculiar coldness and lifelessness, which, indeed, belonged to *Pierre Daret*, the master under whom, for three years, he studied, and who (though a pupil of Bloemaert) is more known by the number of his works (two hundred and ninety-six Engravings) than by their merit.

[*] A renowned follower of Mellan was *Robert Nanteuil*, born at Rheims A. D. 1630, who died in 1678 at Paris, and whose Works during those forty-eight years of life amount to at least two hundred and eighty Plates, (the number in Mariette's collection,) executed with almost unexampled care and precision, and by an artist whose learned education and conversational talents drew him frequently into Society, both among the courtiers of the "Grand Louis," and among men of Letters and Science, his contemporaries. Louis XIV. seems to have created the place of designer and Engraver to the Cabinet purposely to confer on Nanteuil a yearly pension of 1000 livres. The progress of genius in this admirable burinist is traceable throughout his Works. At first, like Mellan, he appears to have worked with single courses of lines: a process exemplified in his portrait of "Louis Hesselin, Counsellor of State." To represent flesh in his portrait of "Christina, Queen of Sweden," 1654, he used stippling only: while for that of "Edward Molé, President of the Parliament," he employed only unbroken lines. In his subsequent labours, Nanteuil appears to have brought together into powerful union the elements of which he had now ascertained the properties peculiar to each. It was to the invention of Nantueil that the Art is indebted for such a combination of lines with stippling, (see first Note to Art. 16.) as has enabled him to express, throughout his carnations, the qualities of softness and firmness, whether in light, shadow, or middle tint; in his representation of human hair, the glossiness and lightness, together with the effects resulting from each variety of colour or of form; and in his draperies, whether furs or silks, linen or woollen, the peculiar texture of every garment. With all this attention to minuter points he was a perfect master of expression. He drew correctly, and his excellence as a portrait-painter in crayons introduced him to his Royal and munificent patron, of whom he painted a portrait. The Art of Engraving he learned, according to some French writers, from his brother-in-law, *Nicolas Regnesson*, of Rheims, who, from being only five years older than Nanteuil, was, in Strutt's opinion, more probably the pupil than the preceptor. Their styles certainly correspond: and Nanteuil's early predilection for Chalcography is evident from his having engraved, while yet a youth at College, his Thesis in Philosophy,

Van Schuppen.

Antwerp contributed a portion of her sons besides Pitau to the French School of Engraving. *Van Schuppen*, the successful pupil of the celebrated Nanteuil, was from Antwerp, as also were *Gerard* and *John Edelinck*, whose talents M. Colbert and the then Court of France were not slow in appreciating and attracting to Paris.*

The Edelincks.

A formidable rival of Nanteuil as a burinist was one who seems to have been his own master in Art, *Antoine Masson*, born at Louri near Orleans, A. D. 1636, whose hand was of necessity made familiar with the graving tool by his having been brought up to the occupation of a gun Engraver. He introduced himself to the Parisian Public as Nanteuil did, by painting portraits. Like Nanteuil, too, he became Engraver to the King; and it was with his burin that he cut out for himself a path to fame entirely new, such as only genius like his could have attempted successfully.† At the

Masson.

Jean Frosne, born at Paris about A. D. 1630, was a very indifferent imitator of Nanteuil. Forty-three portraits, however, engraved by him were thought worthy of a place in the collection of the Abbé de Marolles.

Benoît Thiboust, whose slight, open style resembles that of Mellan, was a French Engraver of this period, who was employed some years at Rome; but he followed Mellan in a very different manner from Nanteuil, and his Plates are miserably defective in taste and correctness.

The family of *Thomassin* also was remarkable at this period. Simon Thomassin, a descendant of Philippe above mentioned, was a burinist who had studied with some reputation in the Academy founded by the French King at Rome. But his style is heavy and laboured, and that of his son Henri Simon Thomassin, born at Paris in 1688, not superior. *Pierre Simon Thomassin*, born at Paris A. D. 1640, was a successful follower of Nanteuil

From the School of Mellan we turn next to that of *De Poilly*. The style of François de Poilly does not sufficiently distinguish drapery from flesh, nor relieve either from his backgrounds. His Plates are covered with rectangular crossings, where powerful second strokes exactly at right angles to the first form a small square between the intersections of almost every four lines. He resided seven years at Rome, where he died at the age of seventy, A. D. 1693. Among his pupils and followers are *Gerard Scotin*, another Parisian, born in 1642, (whose nephew, the *younger Gerard*, in conjunction with Baron and Ravenet, engraved for Hogarth the plates of Marriage à la Mode.) *Jean Baptiste Nollin*, also born at Paris in 1655, has the credit of being one of the best scholars of De Poilly. From Paris, likewise, came *Giles* or *Egidius Rousselet*, born A. D. 1614, who is also reckoned among the followers of Bloemaert. *François Andriot*, born A. D. 1655, whose style is much inferior to De Poilly, yet who scrupled not to engrave after the greatest French and Italian Painters; and *Etienne Picart*, called the Roman from his long residence at Rome, whose son *Bernard* became celebrated for a similar contrivance to that of Henry Goltzius, (Art. 40.) by engraving a set of seventy-eight Plates in imitation of the old Engravers, under the title of *Les Impostures Innocentes*. They were published in one volume after his death, in 1738. *Jean Boulanger*, who was born at Troyes in 1613, and whose father, a Painter, was a respectable pupil of Guido, for some time followed the style of François de Poilly, which he quitted for the dotted system of Jean Morin.

An able scholar, perhaps the ablest of François de Poilly, was *Jean Louis Rouillet*, born at Arles in Provence A. D. 1645. He had studied previously under Jean l'Enfant, a disciple of Mellan, and subsequently qualified himself by ten years of application in Italy to put forth performances worthy of the great masters after whom he employed his graver. His print of the "Marys with the dead Christ," after the celebrated Painting by Annibal Carracci, (which has passed from the Orleans' Gallery into the possession of the Earl of Carlisle,) is one of the most admirable productions of the graphic Art.

But an equally eminent artist, and likewise pupil of De Poilly, was *François Spierre*, who was born at Nancy in 1643, and died at Marseilles only in his thirty-eighth year. He was a Painter of History in something of the style of Pietro da Cortona, (PAINTING, p. 474.) but the Works of his burin establish his claim to admiration. "When Spierre," says M. Watelet, "came to Rome, Cornelius Bloemaert was in the full vigour of his powers and the meridian of his fame. Spierre occasionally imitates him. But both Bloemaert and De Poilly confined themselves to one style; whereas Spierre could vary his at pleasure. He sometimes employed only a single course of lines, which he managed with a degree of ease and freedom superior to Mellan, so that he may be said to have beaten three of the greatest historical Engravers of that Age, each at his own weapons."

Nicholas Pitau, born at Antwerp A. D. 1633, is included by M. Bartsch among the followers of De Poilly, and is supposed to have been a disciple of that master. But Pitau's burin is remarked to be more vigorous and spirited in its execution than De Poilly's. Pitau's "Holy Family," after Raffaelle, is a theme of universal praise for its beauty of handling, purity of drawing, and harmony of effect. His portraits and historical pieces are equally admirable. He died at Paris in 1676.

Guillaume Chateau, or Chasteau, born at Orleans in 1633, was employed and patronized by M. Colbert and the Court of France. He had been a pupil at Rome of the younger Greuter. (Second note to Art. 37.) The Prints which he executed entirely with the graver are in the style of De Poilly and Bloemaert; (Art. 40.) but he was more successful in his later manner. Few ever handled the point with more picturesque freedom, taste, and spirit.

* *Pierre van Schuppen* was born at Antwerp in 1623, whence, after obtaining the rudiments of his Art, he removed to Paris and became the pupil of Nanteuil. At Paris, in the style of that master, he engraved several portraits from his own designs, not inferior to the best productions of that time; (a season of splendid patronage from the Court of Louis XIV.;) and at Paris brought up his son of the same name, called Schuppen the younger, to the profession of an historical and portrait-painter. Schuppen the elder died at Paris A. D. 1702.

Antwerp likewise gave birth to *Gerard Edelinck*, who, as an approved disciple of Cornelius Galle, (Art. 40.) was eminent in his own Country before he was drawn by the irresistible solicitations of the French Minister, in 1665, to the service of the Court of France. Louis XIV. gave him apartments in the Gobelins, a pension, and the honour of Knighthood, which was conferred soon after his admission into the French Academy. Strutt remarks a union of freedom with delicacy in the style of this artist; and Watelet observes of him, that his execution, at once bold and finished, gives a profound feeling of colour; that he is more detailed and perfect (*précieux*) than Bolswert or Pontius, (Art. 40.) without being less picturesque, and that he never produced a Work of mediocrity. Le Brun, therefore, some of whose finest Paintings he engraved, must be pronounced not less fortunate than Rubens. *John Edelinck* was a close but not successful imitator of his brother Gerard; and a son of Gerard, named *Nicolas*, who engraved for the Crozat collection, though not totally discreditable to his father and instructor, was quite unequal to him.

† His Plates reach the number of one hundred and fifteen. "Masson seems," says Strutt, "to have had no kind of rule to direct him with respect to the turning of the strokes; but twisted and twirled them about without the least regard to the different forms he intended to express, making them entirely subservient to his own caprice. Yet the effect he has produced in this simple manner is not only far superior to what one would have supposed, but is often very picturesque and beautiful." In his famous Print after Titian, "Christ with the two Disciples at Emmaus," the eccentricities and originalities of this Engraver are combined with passages of the finest effect. The arms of the figure to the right of Christ, the hat and drapery of the figure on his left, the clouds at the top of the Picture, and under the table a dog which looks, says Watelet, as if made of straw: all these representations seem to defy any prescribed rule. But yet, throughout the Work, so judicious is the keeping, so harmonious and Titian-like the tone of the whole, and so varied the apparent texture of the different objects introduced, that this Plate has been regarded by all subsequent Engravers as an admirable study and model for their guidance. The cloth on the table in this Engraving is so peculiarly finished that the Work has the name of "The Table Cloth;" and a similar circumstance is remarkable with regard to another famous Print, called "The Grey-headed Man," which derives its popular appellation, not from Gillaume de Brisacier, the Secretary to the Queen of France, and the subject of the portrait, but from the admirable execution by which we recognise the white hair and aged complexion of the original. So also the portrait of the Count d'Harcourt is called "Le Cadet de la Perle," on account of the pearl hanging from the warrior's left ear. Masson engraved several heads, the size of life, but in these portraits he has been less happy than in the ordinary operations of his burin. (See Art. 22. and its note.) His daughter, *Madeleine Masson*, born at Paris

The Drevets.

close of the XVIIth and commencement of the following Century the *Drevets*, father and son, are conspicuous among French burinists. *Pierre Drevet the elder* was born at Lyons in 1664, and died in 1739 at Paris. In his native city he received instruction from his townsman, Germain Audran, and afterwards removing to Paris for improvement probably became a student in Engraving under Gerard Edelinck. His masterly command of the graver; his touch firm, yet communicating the most delicate softness; his perfectly correct outline; and a style highly finished as well as implicitly faithful to nature, enabled him to increase and to participate the celebrity of Hyacinthe Rigaud, the great portrait-painter, after whom he engraved. His son, *Pierre Drevet the younger*, was born at Paris in 1697, and died there the same year with his father, of whom Watelet observes, that the elder Drevet, if his son had not exceeded him, might have been regarded as the finest portrait-Engraver that the world has seen.* *Claude Drevet*, a native of Lyons, who died at Paris in 1768, was a cousin and pupil of Drevet the younger. He engraved some highly finished portraits after Rigaud.

Jean Daullé.

Jean Daullé, born A. D. 1703 at Abbeville, was received into the Academy at Paris in 1742; an honour to which his graphic merits fully entitled him. In the *méchanique* of his Art he may compete with almost any of his predecessors; but his drawing does not equal his handling. Watelet highly praises his "Countess of Feuquieres" after P. Mignard, who was the lady's father, and who represents her in the picture holding his own portrait.

John George Wille has been sometimes classed among French Engravers, but we have already spoken of him in the German School. (Art. 39.) M. Bartsch, enumerating the modern burinists of France, instances the Works of *Etienne Fiquet* as being delicately and tastefully finished and highly valued, consisting of several small portraits. He was born at Paris A. D. 1731. *Pierre Savart*, born A. D. 1750, in the same city, follows Fiquet in the same style and with equal success.* *Jean Jacques d'Avril*, another eminent Parisian, born in 1756, was a pupil of Wille.

tienne iquet.

P. Savart. J. J. d'Avril.

(42.) We were next to consider Spanish Chalcographers. For these we search the pages of their Countryman, Cean Bermudez, in his *Diccionario dellas Bellas Artes*, but we search in vain for burinists worthy of mention in the same class with those we have just been enumerating. Minor artists, whose chief employment was to engrave ornamental work, coats of arms, head-pieces, tail-pieces, and frontispieces for books, were to be found in Spain as early as the beginning of the XVIth Century; and the number, whether working with the burin or with the etching tool, or with both, might, throughout the two next centuries, amount to about a hundred, principally from the cities of Madrid, Seville, Valencia, and Zaragosa.† But, on the authority of the Spanish writer alluded to, the Art of Engraving may be pronounced to have scarcely had existence in Spain until after the foundation, A. D. 1744, of the Academy of San Fernando at Madrid: when in a later era simple Chalcography had given place to the modern union of the point with the graver.

But few burinists, simply so called, of *Spain*;

or of *England*.

(43.) Of English burinists in the practice of simple Chalcography we are constrained to make a similar remark. Their number and their merit have been so inconsiderable that we pass them over. In the compound process, indeed, uniting the point with the graver, we shall presently have the agreeable duty of recording them as eminently successful. "The English," observes M. Bartsch, "have not a single master of any great importance who has used the burin alone: but in compensation for this, the number in England is so much the greater who have combined, though often very slightly, the use of this instrument with the previous work of the etching needle, and who in the latter (compound) branch of Engraving have produced the finest specimens of the Art."‡

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about A. D. 1660, engraved some portraits very neatly in her father's style, and some also of the natural size, which latter show the same imperfect and unsatisfactory result, and the same misdirection of valuable time and labour wasted upon the whimsical rage of that day for these colossal performances.

* Drevet the younger, at the age of only thirteen, produced a Plate which was the surprise and admiration of his times; at nineteen he engraved his folio Plate of the "Resurrection," and at twenty-six his celebrated whole length portrait of "Bossuet, the Bishop of Meaux," which is thought his master-piece in portrait, though some prefer his portrait of the "Conseiller d'Etat, Samuel Bernard." This chief of burinists is remarkable for expressing (without any affected display of dexterity in handling his instrument, and yet with exquisite finish) every peculiarity of texture in the surfaces of natural objects. In delicacy he stands unrivalled, though in boldness and picturesque effect others may have surpassed him. Among his historical Prints the "Presentation in the Temple," after Louis de Boullogne, ranks first.

Jaques Lubin, a native of Paris, was a successful follower of Gerard Edelinck, and a contemporary with the elder Drevet. The style of the Drevets seems to have been emulated by *François Chereau*, who likewise studied in the Audran School. Correct design and beautiful execution distinguish his Works; but they betray at the same time a degree of metallic coldness which perhaps the etching needle only could have prevented. His brother and pupil *Jaques*, who died at Paris in 1757, was an estimable artist in the same style, who, in later life, quitted the management of his burin for that of a Print-shop. *Nicolas Gabriel Dupuis*, finding his health impaired by the steams of aquafortis, quitted etching for the use of his graver only. Another pupil of the Audran school was *Nicolas Dauphin de Beauvais*, a native of Paris, who engraved a Plate from Sir James Thornhill's Paintings in the dome of St. Paul's, (PAINTING, p. 485.) and whose style, much applauded by Huber, resembles in his best Plates the style of Edelinck.

* *Charles Clement Bervic*, another Parisian, born A. D. 1736, was a pupil of J. G. Wille, and was received into the Royal Academy of Paris in 1784. He was also a Member of the Institute and Chevalier of the Legion of Honour. With the fault of occasional fondness for gloss and glitter he is designated as being confessedly the ablest burinist of his day and an excellent draughtsman. His Louis XVI. after Callet; his "Nessus and Deianira" after Guido Reni; and above all his Laocoon from the Musée Napoléon will always remain chefs-d'œuvre among the chalcographic specimens of France. *Maurice Blot*, born at Paris A. D. 1754; *Pierre Audouin*, famed both for historical pieces and for his portrait of Louis XVIII.; *R. U. Massard*, celebrated for his peculiar talent of Engraving from sculpture; and *Augustin Boucher Desnoyers*, of whom, as still living, we prefer to repress our criticism, are names worthy of the Art and of their Country.

† See Note (Z.) at the end of ENGRAVING.

‡ Although the art of taking impressions from metal Plates was not known or practised in this Country till long after its invention, yet the use of the burin for engraving plate, armour, jewellery, &c. is of very ancient date in England. The engraved Plates on some of the oldest tombstones and monuments in many of our Churches, testify no ordinary skill of the burinist considering the early period of those performances. Specimens are not unfrequent of which the workmanship may be traced to the first half of the XIVth Century. But the best of these seem to bear no comparison with Works long previous by Anglo-Saxon artists, as appears from the relic preserved at Oxford, termed Alfred's jewel. That enlightened person was an encourager of Works of taste; but the influx of Danish barbarism which followed his reign soon swept away almost all traces of refinement. The superiority of Saxon artists in the kindred Art of Coining has already been noticed. (Note (A.) at the end of ENGRAVING.) On the subject of ancient graphic Works in Britain we refer the reader to Strutt's Essay

The Dry Point.

The *dry point* another simple process in Chalcography.

(44.) The second simple process in Chalcography (Art. 34.) is performed by the Dry Point. (See 2d note to Art. 19.) For this process the preparation of the outlines on the copper-plate is the same as for working with the graving tool or burin.* The forms outlined on the copper are then filled in with shadings cut into the metal by means of a sharply pointed needle, which, when ground in a groove on the whetstone, must be carefully preserved in its conical shape, and free from any angular edge; otherwise it will not mark the plate evenly, but must produce irregularities and roughnesses. As soon as one course of strokes for shading is completed, the bur which has been raised in making them is cleanly scraped away. A second course of lines is then proceeded with; and afterwards, if necessary, a third, in a similar manner.†

Andrea Meldolla.

The first introducer of the dry point upon plates of metal for the purpose of obtaining printed impressions is unknown. *Andrea Meldolla*, who, according to the Abbé Zani, (*Materiali*, p. 207.) has been by all previous biographers confounded with Andrea Schiavone, is represented by M. Bartsch as having been the earliest who brought this mode of operation into frequent practice.*

The dry point (so termed to distinguish it from the etching needle, which it only differs from in being used on the dry, naked, or unvarnished copper) has seldom, except by some remarkable artists, been used alone. The use, indeed, of this instrument as an auxiliary is now universal. It has been chiefly employed in combination with the graver, with the process of etching, or with both. Of the celebrated *Rembrandt*, (see Painting, p. 482.) six pieces are enumerated by M. Bartsch as being produced by the needle only, unassisted by the action of aquafortis or etching.† Of the dry point alone, a landscape called "The Canal" may be quoted as one of the most remarkable specimens. For the simple process of etching only, to which we shall presently come, "Joseph relating his Dream" may be referred to as most admirable: and thirdly, for the perfections of etching and of the dry point united, we turn to his chef-d'œuvre, the "Hundred Guilders" Print, so called from that sum (about £10) having been the price of an impression soon after its publication. It represents the Saviour healing the sick multitude. A portrait of Rembrandt's munificent patron, the "Burgomaster Six," combines, it is thought, all the various modes. The death of Rembrandt is dated by Strutt A. D. 1764; by Bartsch 1668. The last-mentioned writer published at Vienna, in 1797, a complete catalogue, which no collector should be without, of the prints of Rembrandt.

Rembrandt.

Claude Henri Watelet.

Among French artists, an amateur and able writer upon the Fine Arts, *Claude Henri Watelet*, born at Paris A. D. 1718, whose pages in the *Encyclopédie Méthodique* attest his good taste and extensive research, made several not altogether unsuccessful attempts to execute with his own hands some large Plates by means of the dry point only. He died A. D. 1786.

In England, two names are conspicuous in modern

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attached to his *Dictionary of Engravers*. The fifth volume of Walpole's *Anecdotes of Painting* is devoted to English Engravers, commencing in the reign of Henry VIII. with *Thomas Geminus*, or *Geminie*, A. D. 1545, whose anatomical Plates for a new edition of Vesalius are, says Ames, (*Typographical Antiq.* p. 218.) "some of the first examples of rowling press printing in England." A subsequent Edition in 1552 was dedicated to King Edward VI. A former engraved Work. however, had been already published by Thomas Raynalde in 1540, entitled *The Woman's Book*. In the succeeding reign of Elizabeth, Archbishop Parker is distinguished as a patron of the Art, giving employment to a Printer and two Engravers in his Palace at Lambeth. The Archbishop's portrait, by Remigius Hogenburgh, was the first Engraving of the kind, according to Vertue, that has appeared in England. *Wenceslas Hollar*, *Francis Barlow*, and *William Faithorne the elder*, in the reigns of Charles I. and II., *Nicholas Dorigny*, knighted by George I., and *George Vertue* the antiquary (from whose papers the Walpole *Anecdotes of Painting* are compiled) are well-known names creditable to the progress of Engraving in this Country. The numerous portraits by *Faithorne*, executed almost entirely with the graver, are admirable performances, and in deservedly high estimation.

* See Note (A A.) at the end of Engraving.

† The number of impressions which can be taken from a Plate executed with the dry point depends (as in every other kind of Engraving) upon the delicacy of the work. But it seldom yields above one hundred and fifty good impressions; and requires to be hot-pressed, as well as to be under the management of a careful and skilful pressman. The use of the dry point in the first instance calls for great practice and much ability on the part of the Engraver. He may with tolerable facility produce strokes in a straight direction, but he will find bold curved lines very difficult, as the force which he must employ for entering the metal is scarcely compatible with freedom of handling. Plates, therefore, thus executed can be only scratched in a superficial manner, and can never give effect to strong dark shadows. On this account the dry point is suited only to Prints of small size; or if employed on larger Plates the strong shadows should be previously etched. (Art. 45.) Some artists, in order to accomplish dark tones, omit to use the scraper, and leave untouched on the copper the bur (Note (AA.) at the end of Engraving) thrown up by the needle-point. A rich velvet-like black is thus produced by the quantity of printing ink which clings to the lines in this rough state; but the effect is of short duration, becoming necessarily fainter every time the pressman wipes the Plate, (Note to Art. 32.) until the tone originally given is quite lost. In small heads and figures, the dry point, by its thin delicate lines, gives admirable softness to the carnations. The lines scratched by this instrument come out as clear in the impression as those cut with the burin; but have a wiry appearance, are seldom free, and their delicacy approaches often to feebleness. Straight lines, indeed, or lines but slightly curved, may be well marked and made scarcely distinguishable from those cut with the graver. Dots with the dry point are discernible by their perfect roundness and clearness; whereas dots made with the graver are pointed. (Notes to Art. 16.) Dots in etching are of an oblong form and rough.

* See Bartsch's *Anleitung*, &c. vol. i. sec. 440. *Son chef-d'œuvre*, says the Abbé Zani, speaking of Meldolla, *qui représente l'enlèvement d'Hélène en deux feuilles, est marqué* A. M. *et de ses noms de baptême et de famille.* The greater part, if not all the Works attributed to Meldolla, show his use of the dry point; and though some evince a few superadded touches of the burin, none of them have been etched. He apparently worked, says our author, (*Peintre Graveur*, vol. xvi. p. 38.) upon tin plates, of which the few perfect impressions that could be taken (rarely more on copper than one hundred and fifty) make good specimens from the hand of this artist very scarce. They appear, with few exceptions, to be after designs of Parmegiano, for whose Works they have sometimes been mistaken; but the drawing of Meldolla, compared with that of his model. is often faulty and almost always betrays carelessness. The difference, however, is so little between Meldolla and Schiavone that they are still regarded by good critics as one and the same person.

† The following Plates, seven in number, by Rembrandt, are entirely wrought with the dry point unassisted by etching; namely, the "Ecce Homo," dated 1655; the "Three Crosses," 1653; the "Skater;" the "Canal," a landscape; the "Group of Trees," a landscape; a portrait of the "Elder Haaring;" another of the "Burgomaster Six;" and "The Painter after the Model." In the two last-mentioned pieces the burin also is introduced, but not etching. Perhaps no artist has used the dry needle, even upon previously etched Plates, so frequently and so successfully as Rembrandt. A great number of his Plates are very lightly etched, often only etched in their outline, and afterwards finished with the dry point, and having even the strongest shadows put in by the same instrument. As examples of this we refer to his "Hundred Guilders" Print; to his "Faustus;" and to his portraits of "Abraham France," of "John Lutma," of "Ephraim Bonus," and of "Johann Sylvius."

Thomas Worlidge.

Art for this style of Engraving. *Thomas Worlidge*, a native of London, flourished about A. D. 1760. He was a painter of miniatures, and his drawings on vellum in Indian ink and black-lead are held in great estimation. He attempted portraits in oil, but not finding the encouragement he expected, he applied himself wholly to Engraving. He published and became celebrated for several half-lengths scratched in the style just mentioned of Rembrandt with the dry point, to the number of about fifty, one of them a copy of the "Hundred Guilders" print. A complete set of his numerous similar Engravings (a series of one hundred and eighty plates) from antique gems, is also very valuable. He likewise executed some larger historical prints, to which M. Bartsch concedes the praise of considerable ability. He died at Hammersmith in 1766, aged about sixty-five.

Inigo Spilsbury.

Inigo Spilsbury, the next example to be mentioned, was born in 1730, and was residing as a printseller in London about A. D. 1760. Besides some works in mezzotinto, he engraved and published in numbers a set of fifty plates of gems. But he is chiefly to be here noticed for several small half-lengths and heads to the amount of about twenty-four, in Worlidge's manner, though by no means equally tasteful and artist-like with those of Worlidge. Among our own amateur Engravers to compete here with Watelet we must not omit to mention a distinguished native of Ireland,

Captain Baillie.

William Baillie, born about A. D. 1736, who after retiring from the army with the rank of Captain of Cavalry devoted his remaining life to the Arts. Captain Baillie engraved about one hundred Plates in various manners, but his most admired productions are after Rembrandt in the style of that master.

Etching.

Etching, a
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(45.) Etching, the third Chalcographic process, which we have denominated simple, (Art. 34.) is in fact less so than either of the two foregoing, and comprises many essential as well as adjunctive particulars. It is called etching from the German *ätzen*, signifying corrosion; and the Germans, accordingly, who were among the first to practise it, give the term *ätzwasser*, or *etching-water*, to the dilution of aquafortis employed for the purpose. Leaving to a note (see (BB.) at the end of ENGRAVING) our description of the process, we proceed to an enumeration of our examples in this branch of the Art. On the subject, however, of etching, the same remark must be premised which was made respecting the dry point; namely, that it is seldom practised singly, but is almost always auxiliary to or assisted by other processes.

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The origin of this ingenious substitute for the work of the graver was probably German. *Parmegiano* (PAINTING, p. 477.) seems to have introduced it into Italy, previously to whom *Albert Durer* (*Ibid.* p. 485.) practised it in Germany, as appears by the Print by Durer of St. Jerome, bearing date A. D. 1512; but that Durer was therefore the inventor, according to M. Bartsch's assertion, (*Anleitung, &c.* vol. i. sec. 445.) does not necessarily follow. Like most other inventions, its object was to accomplish with greater facility what had been performed already with much labour by other means. As by the discovery of Printing nothing was at first contemplated beyond a shorter method in imitation of writing; so the first Etchers, whoever they might be, aspired only to the most perfect resemblance of engraved Plates from the hand of the burinist. This idea prevailed even in the time of Abraham Bosse, a French Engraver of considerable merit, who, in a very useful Treatise on Etching, published towards the middle of the XVIIth Century, declares the perfection of Etching to consist in its approximation to the work of the burin. To obtain, therefore, as nearly as possible, the cleanness and sharpness of lines cut by the graver, a hard kind of ground or varnish was used, now long since exploded, through which the lines drawn by the Etching needle might exhibit the cleanest and firmest edge possible for resisting impenetrably all action of the acid poured upon them, and for confining the corrosive liquid rigidly within their channels. A more tractable sort of varnish, however, called soft ground, (note BB.) and more easily penetrable by the Etching needle, was subsequently introduced.

The needle different in its effects from the burin.

Etching was found, in process of time, worthy of being classed separately, and to possess some intrinsic excellences to which few but the most practised burins could attain, yet attainable by every good draughtsman or skilful handler of a crayon pencil.[*]

There is a peculiar charm of freshness in the first thoughts of an eminent designer, which the simple process of Etching has been frequently the happy means of preserving and multiplying. Many excellent Painters have employed their leisure in playful touches of the point or Etching needle. M. Bartsch, in his *Peintre Graveur*, instances several characteristic performances more or less finished of this kind. His first five volumes contain some extremely clever fac similes executed by himself after the masters of the Flemish and Dutch Schools. The same author particularizes in his *Guide to Engraving* the following names of artists whose Plates have been entirely wrought with the Etching needle, or in which the additional touches and finishings by the graver or the dry point are so slight as to be considered next to nothing. From the German School he selects

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[*] The characteristic of Engraving from the burin only, Mr. Gilpin well describes to be *strength*, though seldom unincumbered by stiffness; while the peculiarity of Etching is *freedom*, though at the risk of losing force and wanting harmony, or of being less correct in outline than the slower and more deliberate motions of the graver. "From the shape," says he, "of the Engraver's tool (the burin) each stroke is an angular incision, which form must of course give the line strength and firmness, if it be not very tender. From such a line also, as it is a deliberate one, correctness may be expected, but no great freedom; for it is a laboured line, ploughed through the metal, and must necessarily in a degree want ease. Unlimited *freedom*, on the other hand, is the characteristic of Etching. The needle gliding along the surface of the copper meets no resistance, and takes any turn the hand pleases to give it. Etching, indeed, is mere drawing, and may be practised with the same facility. But as aquafortis bites in an *equable* manner, it cannot give the lines that strength which they receive from a pointed graver cutting into the copper. Besides, it is difficult to prevent its biting the plate all over alike. The distant parts, indeed, may be easily covered with wax," (stopping mixture, see Note BB.) "and the grand effect of the keeping preserved; but to give each smaller part its proper relief, and to harmonize the whole, requires so many different degrees of strength, such easy transitions from one into another, that aquafortis alone is not equal to it. Here, therefore, Engraving (with the burin) hath the advantage, which, by a stroke deep or tender at the artist's pleasure, can vary strength and faintness in any degree." Gilpin, *Essay on Prints*, p. 48.

The value, says M. Bartsch, (*Anleitung, &c.* vol. i. sec. 445.) of Engravings produced by Painters and Etchers, conscious of greater powers in design than in execution, must not be sought for in their style of handling; (that is to say, in any regular adaptation of peculiar lines and cross-hatchings, or in the production of a clear effect by carefully attending to the action of the acid on the metal;) their merit consists chiefly in the drawing, in the expression, or in the grouping: and certainly no style of Engraving could be better suited for such slight drawings as require no great effect of light and shadow.

Umbach. Rode.

only two artists, *Jonas Umbach*, a native of Augsburg, born A. D. 1620, who died in 1700; and *Christian Bernard Rode*, born at Berlin in 1725, who died A. D. 1797, both of them Painters.[*]

Wyck.

Among Flemish artists we might particularize *Thomas Wyck* of Haerlem, who came to England about the time of the Restoration, and was much employed. He painted sea-ports and shipping with small figures.[†]

Guido.

In Italy, *Guido Reni*, whom we have already noticed as of the Bolognese School, (Painting, p. 474. 476.) one of the greatest masters of graceful design, executed a considerable number of charming Etchings. They unite masterly freedom and boldness with the same beauty of expression in the heads, and the same correct drawing in the extremities, as are known proverbially to characterise the Paintings of Guido. He died aged sixty-eight at Bologna, his native city, A. D. 1642. He was emulated very successfully in the use of the point by a contemporary Painter, for some time his pupil, *Simone Cantarini*, called from his birth-place *Simone da Pesaro*, who in Painting as well as in Engraving is allowed to have approached nearer to Guido than any other of his numerous imitators.[‡] The Etchings of Simone, in the style of his master, would not be easily distinguishable from Guido's, but for their comparative deficiency in that correctness, (particularly as regards the marking of the extremities,) and in that taste for which the Etchings of Guido are pre-eminent. Strutt mentions *Giulio Carpioni*, born 1611, a Venetian Painter, in the style of Paul Veronese, (Painting, p. 476.) as a tolerably successful follower of Guido in Etching. *Pietro Testa*, born at Lucca, A. D. 1611, and thence called Il Lucchesino, a pupil first of Domenichino and afterwards of Pietro da Cortona, is another Painter whose Etchings, to the number of about thirty-nine, are held in considerable estimation. They have the merits as well as defects of his Pictures, and, while they discover surprising variety and powers of invention, are too often deficient in expression, neither portraying female grace nor manly beauty. They resemble the mannered style of Antonio Tempesta, but are of superior execution. A Neapolitan Painter, (born A. D. 1632,) *Lucca Giordano*, (Painting, p. 478.) is another pupil and assistant of Pietro da Cortona, who has left some masterly and very spirited Etchings. M. Bartsch (*Peintre Graveur*, vol. xxi. p. 173.) records six specimens in the style of Spagnoletto, the artist's first instructor. *Giuseppe Diamantini*, born about A. D. 1600, in the Province of Romagna, is another Italian Painter whose Etchings, to the number of about forty Plates, are much esteemed and possess a rare union of grace, correctness, and spirit.[*]

Simone da Pesaro.

Carpioni.

Testa.

L. Giordano.

Diamantini.

Compound Chalcography

Wood Blocks applied to Copper-plate Impressions.

Compound Chalcography.

(46.) Having now given some account of three distinct methods of Engraving on metal; which methods, from the circumstance of each being sometimes employed singly and unassisted by the others, we have called simple processes: we proceed to mention several combinations of these either among themselves or with other methods.

Wood blocks applied to copperplate impressions.

Mair.

The first of these compound processes to be mentioned is the union of Wood-Engraving with Chalcography; a method alluded to (Art. 30.) as being considered the characteristic of chiaroscuro printing in Germany. An ancient German master, whose name *Mair*, with the date 1499, is affixed to his productions, has already been mentioned. (Note (W.) at the end of Engraving.) M. Bartsch (*Peintre Graveur*, vol. vi. p. 367.) calls him a native of Landshut in Moravia.[†] The subject being first outlined on metal was then printed and the impression afterwards shaded by means of different blocks. Papillon, however, complains of this outline from copper-plate as greatly inferior to an outline from wood. He calls it poor and scratchy. ***Maigre et égratigné***, says he, ***il n'a ni l'expression ni la beauté de celui qui est gravé en bois.*** He mentions a chiaroscuro Print in his possession from the hand of Abraham Bloemaert, of which the outline had been etched. But, in general, the Prints of Bloemaert thus executed are very spirited and produce a good effect. Among others, we may instance a "Holy Family;" a "St. Simon," with the instrument of his martyrdom; "The Woman with a Veil;" a "St. Jerome," after Parmegiano; and a "Naked Infant," after Titian. M. Bartsch, by some mistake, (*Anleitung, &c.* vol. i. sec. 638.) names *Cornelius* Bloemaert as the

Bloemaert.

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[*] *Jonas Umbach*, of whom mention is made by Baron Heineken, etched with a light and spirited point several landscapes containing cattle and figures. His Plates, of which are extant upwards of one hundred and twenty, are mostly of small size and of an octagon form. *Rode*, the next named artist, who had been successively a pupil of Charles Vanloo and John Restout at Paris, and afterwards a student in Italy, brought back with him to Berlin the power of enriching the Churches and Palaces of his native Prussia with several highly valued Works. He etched a considerable number (upwards of two hundred Plates) after his own historical designs; several of them after the Pictures which he painted for various public edifices. He is described as working the needle after a peculiar manner of his own, rather using it as a brush than a pencil. His Prints are consequently free and spirited, but show marks of haste. It is observed, also of his historical figures, particularly of his females, that they want dignity. His younger brother *Henry*, who died prematurely at the age of thirty-two, was a professed Engraver, and a very creditable disciple at Paris of the famous Wille. (Art. 39.)

[†] *Quoique ses estampes*, says M. Bartsch, *sont gravées d'une pointe légère et qu'il n'y ait mêlé ni burin ni pointe sèche, elles ne laissent pas d'offrir un très-belle effet de clair obscur. Sa façon de graver est reconnoissable aux petits traits entrecoupés qui se suivent d'une manière savante les différentes formes. Ces traits sont plus ou moins serrés mais rarement couverts d'une contretaille. Ses estampes sont très-rares.* (*Peintre Graveur*, vol. iv. p. 137. *et seq.*)

[‡] *Giovanni Batista Bolognini*, born at Bologna in 1611, was a pupil and imitator of Guido. (*Peintre Graveur*, vol. xix. p. 187.) *Giovanni Andrea Sirani* and his daughter *Elizabetta*, (*Ibid.* p. 147. 151.) of Bologna, were also successful followers in this School. He was a favourite scholar of Guido, and etched likewise in a free, spirited style. (*Ibid.* p. 161.) *Giulio Carpioni* of Venice, who in Painting followed the splendid style of Paul Veronese, is recorded likewise by M. Bartsch for his Etchings *à la Guido.* (*Ibid.* vol. xx. p. 175.) Also *Domenico Maria Canuti*, of Bologna, a distinguished disciple of Guido, etched several Plates in the manner of his master, which, though less spirited in execution, are neater and more finished. *Domenico Maria Bonavera*, of the same city, nephew and pupil of Canuti, followed in the same style. His Etchings are finished with the dry point. (*Ibid.* vol. xix. p. 222.)

[*] M. Bartsch gives the names of two modern Painters of Italy, both living in 1821, whose Etchings are remarkable: *Ludovico Sabatelli* at Florence, and *Bartolomeo Pinelli* at Rome. (*Anleitung, &c.* vol. i. p. 196. sec. 452.)

[†] "His mode of operating," says Strutt, "was extremely simple. He first engraved the subject proposed upon copper, and finished it as much as the artists of his day usually did. He next prepared a block of wood, upon which he cut out the extreme lights, and then impressed it upon the Print, by which means a faint tint was added to all the rest of the Work, excepting only to those parts where the lights were meant to predominate, which appear as if heightened with white paint. The Prints performed in the style above-mentioned," continues Mr. Strutt, "are extremely good representations of such drawings."

first who attempted works of this kind. Cornelius was certainly eminent, but not as a Wood-Engraver. He was the youngest of four sons of Abraham above-mentioned, and has undoubted claims to originality on copper, as the introducer of a style afterwards perfected by the great Engravers of the French School, Audran, Baudet, Picart, and De Poilly.

H. Grotius.

A learned antiquarian Work by Hubert Grotius, (Art. 40.) of which Papillon possessed the first volume on Roman antiquities, contains, he says, a portrait of Hubert in the frontispiece, outlined similarly to the above. *Le trait est gravé à l'eau forte et la planche de rentrée en bois.* The same mode of execution is also adopted by Hubert for representing one hundred and forty-one medals of the different Roman Emperors. Papillon further states himself to be the possessor of a "Death of Lucretia," similarly performed, and bearing the date 1612, by *Paul Moreelze*, a distinguished Painter of Utrecht; and particularizes two amateurs and collectors of great celebrity in his day, M. Crozat and the *Count Caylus;* the former as having patronized and the latter as having practised this style of Compound Chalcography.[*] A French artist named *Paul Pontius Antoine Robert*, born at Paris about 1680, is mentioned by M. Bartsch as having etched several of the subjects which were executed in chiaroscuro by Nicolas and Vincent le Sueur (Art. 29. 31.) for the Crozat collection.

P. Moreelze.

Caylus.

Robert.

Kirkall.

We may here subjoin the name of an ingenious Englishman, *Edward Kirkall*, (Art. 30.) who invented a mode of producing Prints in chiaroscuro by a mixture of etching and mezzotinto (Art. 62.) with the assistance of wooden cuts. The outline is boldly etched; the dark shadows are then worked on the copper with the graining tool, and the remaining process for producing demitints and for leaving the high lights is effected by separate blocks of wood.

Prints from *raised work* on metal.

(47.) Being drawn once more to the subject of Engraving in relievo, we may be excused for introducing to the reader in this place a method practised by Mr. Lizars, of executing Engravings on metal so as that the lines of the work may, like those of type or of wood-cuts, form a raised surface.[†] This invention is so recent, as to require every indulgence from criticism, but it promises the means of combining the facilities of copper-plate with the durability of Engravings on wood.

Work of the Burin combined with that of the Etching Needle and Dry Point.

Burin combined with the etching needle and dry point.

(48.) But the sort of compound process, which in modern Art has gained most admirers, and has engaged the attention of the most considerable number of artists, requires next to be remarked upon; namely, the conjunction of etching with the work of the graver and of the dry point. (Art. 33. 44. 45.) According to this combined arrangement, each of these three modes of Engraving is made available, on one and the same copper-plate, to the representation of such objects as each is best adapted to delineate.[*]

(49.) To give more than a very select number of the artists who have been distinguished in the compound process now under our consideration would be to transcribe a whole Dictionary of graphic biography. We shall therefore limit our attention to comparatively a few in each of the European Countries before mentioned, and we propose to divide works of this kind into two classes.

Two classes of *compound Chalcography.*

1. Works in which *etching is merely a basis* or initiatory operation, and of which the remainder is completed, partly with the dry point, but chiefly with the graving tool: so that a copper-plate thus executed, possesses all the strength and harmony of an Engraving performed from its commencement with the burin alone. This style of the Art arose only in the beginning of the XVIIth Century.

2. Works in which *etching predominates*, but in which the Plates, after the process of etching, are more or less retouched and strengthened for pictorial effect by the graving tool and dry point. These Prints resemble drawings of which the merit depends on a proper management of light and shade.[†] They have sometimes

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[*] *Traité de la Gravure, &c.* vol. i. p. 396, 397. 400. 406.

[†] On a well-polished plate of copper (a preferable material to lead, pewter, type-metal, zinc, or brass, all of which have been tried) the drawing for the intended Print is made with a pen or hair pencil dipped in turpentine varnish coloured with lamp-black. Let this drawing of varnish be perfectly dry, and then proceed as in etching. (See Note BB.) The acid, poured upon the plate, will remove by its action on the uncovered parts of the copper all the interstices intended to be hollowed out between the lines of the drawing. In dark shading, where the lines are numerous and closely drawn, and the interstices few, this operation is performed without much risk of accident; but if the distance be considerable between the lines, it will be necessary, by a subsequent process, to employ the burin for cutting away the parts which surround them in order to prevent the dabber of the pressman from reaching the bottom, so as to charge it with ink and cause a blurred impression.

The ingenious contriver of this method recommends from experience that the common etching ground be, in the first instance, laid upon the copper; next that with an etching needle the first course of lines, or rather *interstices*, be removed; and, lastly, that over these the artist should put in his cross lines with the varnish. In such parts as require more freedom of touch the etching ground may be scraped away, and the drawing completed with the varnish.

[*] A peculiar excellence of etching consists in its admirable expression of the picturesque in ancient or ruined buildings, in cottages, in rocks, and uneven ground, in the broken trunks, and particularly the foliage of trees, and in its general aptness for portraying vegetation. To characterise such objects, an agreeable roughness, when the acid is permitted to bite freely, is produced; and on the other hand, any required degree of smoothness is equally attainable by reason of the uniform action of the corroding liquid when left to bite the lines evenly and alike. (Art. 19.) The hand also of the operator has the inestimable advantage of applying his etching needle with the same freedom as in drawing with a black-lead pencil.

Etching alone, however, would be feeble and often incorrect. Wherever precision and strength are required the burin is indispensable; and the latter instrument (more especially in portraits, where the most minute parts must be faithfully given) is employed for re-entering the etched lines to give them the requisite sharpness. For engraving also such lines as swell by insensible gradation from a fine extremity to greater thickness, or *vice versâ*, although several etching needles differing in breadth may, one after the other, be used for re-entering the same line; or, although the instrument which Bosse terms an *échoppe* (see Plate i.) may be applied; yet no line of this kind can ever equal in clearness, exactness, and firmness a line cut at one sweep with the graving tool. The now universal practice, therefore, of modern Chalcographers, whether executing the largest or the most minute Works, is first to bring their Plates to a state of considerable forwardness, and to produce all the producible effect by means of *etching:* then, *with the graver*, to harmonize the different masses, and *with the dry point* to tint the lights and more delicate portions of the Engraving. So that Plates professedly wrought by the burin are scarcely to be found without some assistance from etching: while, on the other hand, few copper-plates under the title of etchings are committed to the press without some touches from the graver and dry point.

[†] *Anleitung, &c.* vol. i sec. 445. M. Bartsch has included this class of Prints among his examples of etching; but as in most of them considerable use of the graving tool or burin is introduced, we must, to be consistent, include them among specimens of Compound Chalcography.

been classed with etchings. Their execution, however, advances a degree further than in the Prints we have just mentioned, (Art. 45.) by Rode, Guido, Cantarini, Testa, and others: and which latter may be compared to slight sketches where no peculiar effect from shading is expected or intended.

Italy. *First class of compound Engraving.*

(50.) Respecting the first of these classes of the Art it is to be remarked, that although such a complete union in the operations of the graver with those of the etching needle was not accomplished in the XVIth Century, as was afterwards effected by Gerard Audran, and the French School, towards the end of the XVIIth; yet that the attempt was made long before, and not altogether unsuccessfully in Italy: and as the invention of etching was at first introduced only in the light of a substitute for the work of the burin, no doubt the burinist would more often deem it expedient to retouch his etching with the graving tool, than afterwards; when the peculiar virtues of each process came to be better understood and appreciated. We have already included *Agostino Caracci* (Art. 37.) among the most eminent burinists of Italy. Three others of the same name and family, *Ludovico*, born A. D. 1555, the celebrated founder of their School in Bologna, (PAINTING, p. 476.) with his cousins, *Annibale* and *Francesco*, (but more particularly Annibale,) younger brothers of Agostino, have left us several free and masterly specimens of historical Engraving, partly etched, and then finished with the graver. Their contemporary *Federico Baroccio*, of the Roman School, (PAINTING, p. 474.) was another *peintre graveur* whose Engravings, not, certainly, examples of delicate execution, possess the yet higher claims of correct design and beautiful expression. He died in 1612. An exact account of the Prints by these artists is given in M. Bartsch's seventeenth and eighteenth volumes.

The Caracci.

Baroccio.

We must here, as before, considerably abridge the materials, which with some care we had collected: and in order to preserve our prescribed bounds, can only give in nearly chronological order a few of the names which belong to the succeeding centuries. Such remarks as our space affords will be found occasionally in a note below.

Artists' Names.	Where born and when.		Died at	A. D.
Pietro del Po	Palermo	1610	Naples	1692
*Pietro Testa**	Lucca	1611	Drowned in the Tiber	1650
Carlo Cesio†	Antroduco.	1626		1686
Brothers. *Francesco Aquila*.	Palermo	1676		
Pietro Aquila‡	settled with his brother at Rome about			1700
Cesare Fantelli	Florence	1660	Rome	1752
*Carlo Gregori**	Florence	1719		
Giacomo Frey†	Lucerne	1681	Rome	1752
Giuseppe Wagner‡	Thalendorf	1706		
Domenico Cunego§	Verona	1727		1800
Aloysis *Giuseppe* } his sons	Verona	1757 1760		
Francesco Bartolozzi‖	Florence	1730	Lisbon	1812
Giovanni Volpato	Bassano, about	1738		1800
Raphael Morghen	Naples	1755		

Second class in Italy.

Parmegiano.

(51.) Our second class includes a host too numerous for detail. A number of Painters in the different Schools of Italy have been distinguished in this class as etchers. Most of them will be found in the sixteenth and five following volumes of M. Bartsch's *Peintre Graveur*. *Francesco Mazzuoli*, or *Parmegiano*, (PAINTING, p. 477.) whom we have remarked upon as the introducer of etching into Italy, claims to be first mentioned. He was born A. D. 1503, at Parma, as his popular name imports. We next find ourselves among the Italian artists whom the munificent Francis I. invited to Fontainebleau. (PAINTING, p. 490. French School.) *Lucas Penni*, (a fellow-pupil with his brother Il Fattore under Raffaelle,)

L. Penni.

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* *Del Po* and *Testa* were pupils of Domenichino, Engravers of some celebrity, the former after his master, as well as after the Caracci and Nic. Poussin; the latter after his own designs. Testa studied some time under Pietro da Cortona. (See Roman School, PAINTING, p. 474.) The Works of Testa have been sometimes classed and compared with those of Tempesta, (Art. 45. 51.) but those Prints to which we now allude are more finished, and possess superior execution. For an account of Testa as well as of Del Po, see vol. xx. of the *Peintre Graveur*.

† *Cesio*, another disciple of P. da Cortona, is recorded by M. Bartsch (*Peintre Graveur*, vol. xxi. p. 101.) as the Engraver of ninety pieces, (sixty-four of them subjects from the Farnese Gallery,) *qui offrent un dessein pur et ferme, ainsi qu'une pointe légère mêlée d'ouvrage de burin très-intelligente.*

‡ *Pietro* was an Ecclesiastic and a Monk, but found leisure in his seclusion to become, according to Baldinucci, a respectable Painter. As an Engraver he is better known. His drawing is extremely correct: and his Prints, the best of which are after the Caracci, possess admirable boldness and freedom. Each of the brothers engraved several Plates after P. da Cortona, Ciro Ferri, and Carlo Maratti, (PAINTING, p. 474.) and Pietro was engaged with Cesare Fantelli in a set of fifty-six Prints from the series of Pictures in the Vatican called "Raffaelle's Bible." The first thirty-six are by Fantelli, but are much inferior to the remainder from the hand of Pietro Aquila.

* A Work entitled *Museum Florentinum*, portraying, as its name imports, the treasures of Art at Florence, called forth the graphic talents of several distinguished artists, and among others of *Carlo Gregori*, a pupil of the celebrated Giacomo Frey, above named. Carlo left a son, *Ferdinando*, born at Florence in 1743, who studied at Paris in the School of J. G. Wille, (Art. 39.) and has engraved several Plates of considerable merit.

† *Frey* has been generally put down among the German School, although he must have passed his life at Rome from the age of twenty-two, until his death at the age of seventy-one; and although he was regarded as one of the ablest masters in that city. He left his native Swisserland to become a pupil at Rome, for some time of Westerhout, but afterwards of Carlo Maratti, under whom he was a fellow-student with Van Audenaerde, a future ornament of the Flemish School. Maratti is said to have remarked to his pupils, that a common fault of historical Engravers was to cause hardness in their contours by too frequent use of the burin; that Dorigny in his best Prints had escaped this error; and that by familiarizing their hands to the etching point, they would find it to exceed the graver in delineation of picturesque objects. By the advice of their master, Audenaerde and Frey pursued the same style of Engraving, but Frey with so superior success, as to be sometimes remarked upon as the Gerard Audran of Italy. Raffaelle, Guido, Domenichino, P. da Cortona, and Maratti are the Painters after whom the principal Engravings are executed by this correct and tasteful draughtsman, as well as perfect master of harmonious effect. Few Prints approach nearer to the style of their originals. Good impressions are extremely rare. His son and publisher *Philip* is said to have retouched most unskilfully the worn Plates, and to have destroyed all the harmonious sweetness and delicacy of Giacomo.

‡ This equally celebrated native of Swisserland established himself at Venice. His Works, like those of Audran (Art. 56.) and Frey. show how admirable is the union, judiciously and tastefully made, of etching with the work of the burin and dry point. From his School at Venice have come forth some of the ablest moderns, *Bartolozzi*, *Flipart*, *Berardi*, *Capellani*, and others.

§ Cunego, with Capellani and others, worked for the *Scuola Italica* of Mr. Hamilton. He afterwards came to England, where he engraved some Plates for the Boydell collection.

‖ Dr. Johnson's Epitaph on the Poet Goldsmith may be parodied with strict truth in reference to the indefatigable genius of *Bartolozzi*,—that he left scarcely any species of Engraving "untouched or unadorned by his hand;" but it is to his Works in the class of Art we now consider (such as his "Clytie repulsing the God of Love," after A. Caracci) that he is indebted for his settled reputation. His pupil *Volpato*, whom he taught at Venice, has distinguished himself by several Prints from Raffaelle not unworthy of such an instructor; and from Volpato the same instructions have descended with undiminished force to *Raphael Morghen*, the disciple and son-in-law of the latter.

Leon Davent, and *Domenico del Barbiere* were of that number. The Prints of these Engravers, chiefly after the Works of Il Rosso, Niccolo dell' Abati, and Primaticcio, are the more valuable ever since the barbarous and wanton demolition, in 1738, of the magnificent frescos at Fontainebleau, executed by Dell' Abati, (A. D. 1552, *et seq.*) from the designs of Primaticcio.

Fantuzzi.

Antonio Fantuzzi of Viterbo, a pupil of Primaticcio, has likewise left some bold and scarce etchings from the Works of that master, as well as of Il Rosso.

G. B. Franco.

Giovanni Batista Franco[*] was a celebrated contemporary of these artists.

P.Veronese. Fialetti. G. Palma.

In the Venetian School, the etchings by *Paolo Caghliari*, (PAINTING, p. 476.) known better as *Paolo Veronese;* also by *Odoardo Fialetti*, of Bologna, a pupil of Tintoretto; and by *Giacopo Palma*, (born at Venice in 1544, and surnamed *Il Giovane*, to distinguish him from the elder Palma, his great uncle,) are in great esteem among the curious.

Other artists.

Artists' Names.	Where born and when.		Died at	A. D.
Gio. Bat. D'Angeli, alias Del Moro[†]	Verona	1512		
Antonio Tempesta[‡]	Florence	1555		
Batista Vicentino, flourished at Venice about A. D. 1540.				
Remigio Cantagallina[§]	Florence	1582		
Josef Ribera, alias Il Spagnoletto[‖]	Xativa in Valencia	1589	Naples	1656
Giov. Fran. Barbieri, alias Guercino[¶]	Cento	1590		1666
Giacomo Callot[**]	Nancy	1593		1635

Artists' Names.	Where born and when.		Died at	A. D.
Claude Gelée, alias Claude Lorraine[*]	Champagne in Lorraine	1600		1682
Gio. Fran. Grimaldi[†]	Bologna	1606		1680
Pietro Fran. Mola[‡]	Caldra	1609	Rome	1665
Stefano della Bella[§]	Florence	1610		1664
Gaspar Duchet, alias Gaspar Poussin[‖]	Rome	1613	Rome	1675
Salvator Rosa	Naples	1615	Rome	1673
Giov. Benedetto Castiglione	Genoa	1616		1670
Bartolomeo Biscaino[¶]	Genoa	1632	Of the plague	1657
Pietro Sante Bartoli, called by some Il Perugino[**]	Perugia	1635		
Marco Ricci	Belluno	1680	Venice	1730
Giov. Batista Tiepolo[††]	Venice	1697	Madrid	1770
Francesco Londinio	Milan	1723		
Benigno Bossi[‡‡]	Milan	1727		

Germany. First class in compound Chalcography. Bause.

(52.) Turning next to GERMANY, for a first class of Chalcographers (Art. 49.) in this mixed process, we find the name of *John Frederic Bause*, in a list by M. Bartsch, (*Anleitung*, &c. vol. i. p. 223.) next to the name of J. Frey, whom we have already mentioned, (Art. 50.) Bause was born at Halle in Saxony, A. D. 1738. He

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[*] *Franco* formed his style of Painting upon the study of Michel Angelo Buonaroti, and though not successful as a colourist, is considered by Lanzi as one of the ablest examples of Florentine Art. His Plates, to the number of about ninety, are carefully divided by M. Bartsch into four sections, all of which he considers to have been more or less etched: the first section very little; the three last evidently so; and in the fourth he considers the burin only applied to lengthen out into fine points, those lines which the aquafortis would necessarily leave in a blunted state.

[†] Styled *Del Moro*, from having been the scholar of El Moro. (Francesco Torbido.) D'Angeli was in Painting a successful competitor of Paolo Veronese. His slight and spirited etchings are remarkable for delicate and masterly drawing in the extremities of the figure. In conjunction with Batista Vicentino, he engraved fifty landscapes, chiefly after Titian. His son *Marco* is likewise chronicled by M. Bartsch among the etchers.

[‡] A Painter of battle-pieces, whose inventive powers and great fertility are manifested in his numerous etchings, consisting of more than eighteen hundred.

[§] Pupil of the Caracci, though not distinguished as a Painter, and instructed in Engraving by *Giulio Parigi*, jointly with whom he engraved some plates of opera scenes. The School of *Canta Gallina* at Florence became celebrated, as Gori relates, for producing *Stefano della Bella*, and *Jacques* or *Giacomo Callot*.

[‖] *Spagnoletto*, and his sometime pupil *Salvator Rosa*, (PAINTING, p. 478.) gave celebrity to Naples in this Art. The former has left about twenty etchings, producing, in a bold and free manner, the finest effect. The latter has left about ninety, of which the masterly chiaroscuro and characteristic expression, particularly in the heads of his figures, are admirable.

[¶] A few etchings from the hand of this Painter, one of the lights of Bologna, (PAINTING, p. 477.) show great taste and spirit.

[**] His Prints amount to upwards of fifteen hundred. *Callot* is most successful where he has confined himself to small figures. He used for his Plates the hard varnish, which soon after his time was abandoned for the modern more convenient material. (Note (BB.) at the end of ENGRAVING.) His powers of invention were extraordinary. His practice was to make several designs for a subject before he could engrave it to his satisfaction. Watelet declares that he saw four different drawings by Callot, for his celebrated Plate of the "Temptations of St. Anthony." A courageous reply made to Richelieu, the powerful and resentful Minister of Louis XIII., is recorded of this Engraver, after he had been employed sometime at Paris to engrave the principal sieges and battles of the French, particularly those of Rochelle and Rhé. On being pressed by threats, after he had made several requests to be excused, to furnish a drawing, and engrave a similar Plate of the siege of Nancy, his native city, taken by the French in 1631, he replied, "I will sooner cut off my right hand, than employ it in any act disrespectful to my Country, or disloyal to my Prince;" alluding to the Duke of Lorraine, whose dominions were not then formally appended to France, but had been overrun, together with Nancy the Capital, by the French armies during Richelieu's darling contests with Austria. Louis, more generous than his Minister, was so struck with this patriotic answer, that he offered Callot a handsome pension, which he nobly declined. Notwithstanding this plain refusal of Callot himself to be deemed a Frenchman, his chroniclers have enrolled him among French Engravers, together with his inimitable fellow-countryman, Claude Gelée, or *Claude Lorraine*, who also passed his best days in Italy, and died at Rome in 1682, before his native Province was ceded to France. (PAINTING, p. 491.)

[*] *Claude* etched several landscapes and seaports, to the number of about twenty-eight Plates. They are, in general, good compositions, but are indifferently executed.

[†] Called *Il Bolognese*, from his native city; an admirable Painter and Etcher of historical landscape.

[‡] This distinguished Painter of History, and more particularly of landscape has left some spirited etchings on historical subjects. He settled at Rome.

[§] His Plates exceed fourteen hundred. He imitated at first the style of Callot, his fellow-student under Cantagallina, but abandoned it for another of his own, of which a brilliant and clear execution, as well as tasteful and spirited design, are the general characteristics.

[‖] He acquired the appellation of *Poussin* from the marriage of his sister with Nicolas Poussin. The few slight etchings from this great master of landscape are precious to every collector. His younger brother, *John Duchet*, devoted himself to Engraving, but not with much success.

[¶] *Biscaino* and *Castiglione* were both eminent Etchers; they bear some resemblance in style to each other. Castiglione, in particular, approaches to the magical chiaroscuro of Rembrandt. He was at one time apprenticed to Vandyke, during the stay of that great master at Genoa. The etchings of Biscaino, who unfortunately died young, are full of intelligence and graceful expression.

[**] He quitted Painting for Engraving. His Plates are numerous, are chiefly etched, and are distinguished for dexterous and masterly handling of the point.

[††] *Ricci* and *Tiepolo* were eminent in the Venetian School. The former, a nephew and pupil of Sebastiano Ricci, (PAINTING, p. 476.) etching landscape from his own designs. The latter, together with his son *Giovanni Domenico* and grandson *Lorenzo*, etched as well as painted with much taste and spirit. The frescos by the elder Tiepolo, in the new Palace at Madrid, are splendid specimens of his powers as a machinist, and even gave alarm to Mengs, the popular Court painter.

[‡‡] Of these contemporary Milanese artists, the former, *Londinio*, a Painter of history and landscape, has etched about seventy landscapes in a very pleasing style. The latter quitted Painting by the advice of Mengs, and devoted himself to Engraving. Under the patronage of the Duke of Parma, *Bossi* performed several spirited Works, some of which entitle him to rank among the preceding class of Engravers.

M. Kusell. Kraus.

is said to have been a self-taught artist, and to have acquainted himself with the Art, by a careful study of the works of J. G. Wille. (Art. 39 and 41.) His Prints have considerable merit, and evince both in portrait, and in several historical Plates, a complete and firm command of the graver. Earlier combiners, however, of the burin with the etching point in Germany might be named, such as *Matthew Kusell*, born at Augsburg, A. D. 1622; and *John Ulric Kraus*, of the same city, born in 1645, a pupil of Melchior Roos, (Art. 53.) whose daughter he married. He completed three sets of Plates for three successive editions of the Bible, and followed with some success the style of Sebastien le Clerc. (Art. 56.)

Guttenburg. Gmelin.

Charles Guttenburg was a pupil of Wille at Paris, and has produced several Plates in the style of his master. He was born at Nuremburg in 1744. He engraved for the Work of the Abbé St. Nun, entitled *Voyage Pittoresque du Royaume de Naples*. There is a neat copy by him of Woollet's celebrated Print, the "Death of General Wolfe." Another artist, one year younger than Guttenburg, and who adopted the manner of Woollet, was *Frederic Gmelin*, a native of Badenweiler on the Rhine, in the neighbourhood of Fribourg. He is distinguished by M. Bartsch as having engraved landscapes after Claude Lorraine.

The Preislers. Leybold.

The family of *Preisler*, natives of Nuremburg, have been industrious in the Art. Three brothers of this name, born between A. D. 1698 and 1716, sons of an obscure Painter, became respectable artists, but particularly the youngest of the three, *John Martin Preisler*, who in 1739 visited Paris and received instructions from Geo. Fred. Schmidt. He afterwards became Engraver to the King of Denmark, and member of the Academy at Copenhagen. His son *John George* was a creditable pupil of Wille, and in 1787 a member of the Academy of Paris. *John Frederick Leybold*, (born at Stutgard in 1756,) Professor of Engraving in the Royal Academy of Vienna, is celebrated for a "Death of Marcus Antonius" after Pitz.

Germany. Second class in compound Chalcography. The Merians. Rosa da Tivoli. Ermels.

(53.) For the second class of German artists in this way, we have already named some examples of early etching. (See Note (U.) and Note (W.) at the end of ENGRAVING.) The few etchings of Albert Durer are not equal to his Engravings with the burin only. (Art. 39.) In the city of Frankfort arose the family of *Merian*,* whose contributions are highly celebrated and valuable in this class of Art. *Rosa da Tivoli*, born at Frankfort in 1655, whose real name was *Philip Roos*, found leisure from painting to contribute some rare specimens. The family of *Roos* were admirable etchers.* Among celebrated moderns we have mentioned the name of Sandrart. (Art. 39.) That family was also eminent in this department.† Their contemporary at Nuremburg, *John James Ermels*, imitated as a Painter the style of John Both, (PAINTING, p. 484,) and etched very tastefully a few landscapes.

The Kusells. Umbach. Ridinger. Maur.

The family of *Kusell* at Augsburg (Art. 52.) has been creditable to the Art.‡ *Jonas Umbach*, of the same date and birthplace, ranks with some in considerable estimation. An eminent contemporary Painter, *John Elias Ridinger*, who established himself in that city,§ has left several unrivalled etchings of wild animals. *John William Maur*|| of Strasburg was another Painter of some eminence whose Engravings deserve attention.

Botschild. Thiele's. Dietrich.

We have had occasion to remark the progress of Dresden in the Fine Arts. *Samuel Botschild* and *John Alexander Thiele* were Saxon artists, patronised by the Court of Dresden at the end of the XVIIth and towards the middle of the XVIIIth Century. *Dietrich*, a pupil of Thiele, was another Saxon who has done honour to the same patronage.¶

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* *Matthew Merian the elder* was born at Basle in 1593. He married the daughter of his eminent graphic instructor Theodore de Bry or Brie, and had for his disciple the celebrated Hollar, whose talents afterwards promoted and advanced, if they did not rather originate, our English School. His typographical Plates, like those of his pupil, are exceedingly valuable and faithful representations. He died in 1651. *Matthew Merian the younger*, his son, was a respectable Painter, and studied successively, it is said, under Sandrart, Rubens, and Vandyke. He engraved the portrait of Dr. Donne, prefixed to an edition, in 1640, of that author's Sermons. *Gaspar Merian*, a younger son, also engraved. But *Maria Sybilla*, their sister, was the most eminent of the family. To gratify her enthusiasm as a naturalist, she undertook a voyage to Surinam, and returned (but not until forced by injury to her health) with numerous drawings and specimens of insects and plants peculiar to that climate. Of these she published an account at Amsterdam in 1705. Previously to this remarkable voyage, she had published at Nuremburg, in 1679, her interesting history of the insects of Europe, accompanied with Plates from her designs, and partly etched by herself. Two large volumes of the drawings for these Works are preserved in our British Museum. She engaged her two daughters, who, like herself, were admirable flower-painters, in the same labours, and they contributed after her death to complete them.

* *Philip Roos*, during his term of study in Italy, kept a kind of menagerie of animals at Tivoli for the pupose of drawing them with the greater correctness; hence his Italian sobriquet. He was a judicious and tasteful Painter of landscape and animals. His few etchings of pastoral subjects are extremely rare. He found a liberal patron in the Landgrave of Hesse, and died at Rome in 1705. His father, *John Henry Roos*, was eminent in the same walks of the Art. From anxiety to rescue some valuables from fire out of his house at Frankfort, Henry fell a victim to the flames. *Theodore* was another son whose etchings are as beautiful as they are scarce. *John Melchior*, a younger son, has left one etching of which M. Bartsch praises *la manière savante*.

† *John James Sandrart* (a great nephew of the Painter and Antiquary) contributed, together with his sister *Susanna Maria*, to embellish with many spirited etchings the publications of their learned relative Joachim. John James died at Nuremburg in 1708.

‡ *Melchior Kusell*, born at Augsburg A. D. 1622, was a pupil of Matthew Merian. About one hundred and forty-eight etchings representing Italian seaports and views, &c., together with a variety of subjects after William Baur from the "Life of Christ," comprise the chief of his performances.

§ His ability has been seldom surpassed in the numerous excellent etchings which he has left, chiefly of wild animals and huntings, most appropriately grouped in the wildest forest scenery of his Country.

|| *Maur*, who had passed some years at Rome under the patronage of the Prince Giustiniani and the Duke of Bracciano, was taken into the employment of the Emperor Ferdinand III. at Venice, in whose service he died in 1740. His Plates from the *Metamorphoses* of Ovid are respectable performances, and much resemble the manner of Callot.

¶ *Botschild* was born at Sangerhausen in 1640. His reputation gained him the appointment of Painter to the Court of Dresden, and Keeper of the Electoral Gallery. He founded in that city an Academy for the young artists of his Country. His etchings on historical and emblematical subjects are from his own designs. His Countryman *Thiele* composed landscapes from the charmingly picturesque banks of the Sala and the Elbe. Many etchings of these views, dated from 1726 to 1743, (the latest are the best,) remain from the hand of Thiele. *Dietrich* was born at Weimar in 1712, and in 1742, under the patronage of the Court of Dresden, visited Italy, where he studied some time at Rome and Venice. His style, however, remained entirely German. He was an excellent colourist, and could imitate with surprising facility and address the Works of Rembrandt, Ostade, Polemberg, Salvator, &c. His etchings in imitation of these masters are in high esteem, to the number of about two hundred Prints, some of them extremely scarce, from the circumstance of his having frequently destroyed an

Crodowieki, Weirotter, Gessner, and others.

Daniel Crodowieki, born at Dantzic in 1726, is one of the most remarkable moderns in this species of Engraving. *Weirotter*, *Gessner*, *Ferdinand* and *William Kobell*, and *Charles Weisbrod*, are also well-known names with which we here conclude our German list.*

First class, in Flanders and Holland.

(54.) From what we have recorded of the Flemish and Dutch School, (see Art. 40. and Painting, p. 479, 482, &c.) our readers will anticipate (as a natural consequence of the indefatigable genius which presided in that numerous fraternity) no less industry and originality in this than in every other arena of pictorial ambition. In our first class, however, now to be considered, (Art. 49.) only two artists have drawn the attention of M. Bartsch, (*Anleitung*, &c., vol. i. p. 228.) *Robert van Audenaerde* and *Arnold van Westerhout*.† Several others antecedent to them might be named.‡

Audenaerde. Westerhout.

W. de Leeuw. Neefs.

In Flanders, the cities of Antwerp and Ghent produced some able Engravers whose talents as burinists gave them facility in this compound process. Antwerp gave birth, in 1610, to *William de Leeuw*, and in or about 1630 to *James Neefs*. Their Prints after Rubens, Vandyke, and other Painters of that School, are highly characteristic, though Neefs is occasionally mannered and rather extravagant, and De Leeuw sometimes coarse and inharmonious. Westerhout was of the same city, born in 1666. From Ghent, the birthplace of Van Audenaerde, came likewise *Francis Pilsen*, his pupil, born a. d. 1676.

Pilsen.

Second class, in Flanders and Holland.

(55.) The second class in this species of mixed Chalcography is, as might be expected, much more numerous. M. Bartsch, however, particularizes only those in the ensuing list, of whom, with their principal disciples and followers, the reader will expect some mention.

Artists' Name.	Where born and when.	Died at	A. D.
*Paul Rembrandt van Rhyn**	Near Leyden.....1606.	Amsterdam,	1674

Engraving (after taking a certain number of impressions) in order to use the same plate again.

* "*Crodowieki*," says M. Bartsch, "has been to Germany, what Gravelot, Eisen, and Nicolas Cochin have been to France, an admirable illustrator of printed Works. (*Anleitung*, &c., vol. i. p. 200.) His peculiar merit lay in delineating character (even in very diminutive figures) through every variety and degree, whether of quietude or of emotion: and he is excellent, like Hogarth, in the choice and disposition of judicious accessories." M. Bartsch predicts also that his Works, like those of Hogarth, will command admiration long after changes in modes of dress (often a great essential towards marking character) shall have arisen to diminish popular interest. Crodowieki died in 1800.

Francis Edmund Weirotter of Inspruck exercised his etching point on the most picturesque and appropriate subjects with great harmony, beauty, and force. His figures are well designed and cleverly introduced. He died at Vienna in 1773, at the age of forty-three.

The poet *Gessner* was likewise a pleasing and very finished etcher of landscape. He etched for his celebrated Poem, the *Death of Abel*, several vignettes and ornamental pieces. One set by him of ten landscapes is dedicated to Watelet.

William Kobell was the son of *Ferdinand*, and was born at Manheim about a. d. 1766. Both have etched some most desirable Plates of landscape, but especially William, whose graphic productions have most successfully characterised the principal landscape-painters of the Dutch School.

Weisbrod, born at Hamburgh in 1754, was a pupil of Wille. The landscapes are very numerous from his hand, in the neat clear style of his master. He also engraved after Pynaker, Ad. Van de Velde, Ruysdael, &c. (Painting, p. 483, 484.) and assisted in some Plates for the Cabinets of Poullain, Choiseul, and Prasin.

† *Audenaerde* has been already remarked upon as a fellow-student at Rome with James Frey (Art. 50.) under Carlo Maratti. He became, by the instructions of that master, a respectable Painter of History; and painted several Pictures for the Churches and Convents of Ghent, his native city. He died in 1713. His Works as an Engraver are chiefly after Maratti, and are unequal in their execution. Those in which he accompanies the graver with the etching point are decidedly his best. He was an admirable draughtsman, and has shown a perfect acquaintance with the human figure.

Westerhout, who pursued the same style of Engraving, is said to have sometimes worked with him on the same Plate. But, although Westerhout chiefly used the graver, he wants force, and fails of any powerful effect. He was a native of Antwerp, but established himself at Rome, where he engraved portraits and History as well from his own designs as from Works of Italian Painters, and died a. d. 1725.

‡ Without going back to *Lucas van Leyden*, the founder of the Art in Holland, (Painting, p. 480. and see Art. 40.) we might again mention *Peter Soutman* of Haerlem, the scholar of Rubens, (*Ibid.* p. 482. and Art 40.) and his pupils *Cornelius Visscher*, also of Haerlem, *Peter van Sompel* of Antwerp, and *Jonas Suyderhoef* of Leyden: together with their contemporaries at Haerlem, *Peter Holstein* and his son *Cornelius*, born at Haerlem about a. d. 1620; and *Theodore Matham*, about ten years earlier. *Abraham Conrad*, of somewhat later date, a successful imitator of Vostermanps, (Art. 40.) is eminent for some very fine portraits.

Other Dutchmen might be added, as *Henry Goltzius* of Mabrecht; (*Ibid.*) *Simon Frisius* of Lewarden in Friesland, born a. d. 1590, one of the first who brought etching to perfection; *Romeyn de Hooghe* (Art 55.) whose well-known Print of the deluge at Coeverden is well described by Mr. Gilpin; (*Essay on Prints*, p. 208.) and *Jacob Houbraken* of Dort, who with his father was established at Amsterdam. (Art. 40.) Amsterdam was the birthplace, in 1634, of *Abraham Blooteling*; in 1655 of *Solomon Savery*; and in 1670 of *Matthew Pool*; all of them eminent Engravers of this class. The same city, in the following century, gave birth to *John Punt* and *Jacob Vander Schley*.

* *Rembrandt Gerretz*, or Rembrandt *van Rhyn*, was so called from the house of his birth, where his father, a miller, resided on the banks of a canal supplied by the waters of the Rhine between Leyendorp and Hoerke near Leyden. We have already (Painting, p. 482.) invited attention to the merits and singularities of this great master of chiaroscuro. The engraved Works, according to M. Bartsch, of this extraordinary artist amount to more than three hundred and seventy pieces. Among these he distinguishes the "artist's own portrait with a sabre;" (his portraits of himself are twenty-seven in number;) the "Raising of Lazarus;" the "Hundred Guilders" Print already mentioned; (Art. 44.) the "Good Samaritan;" the "Skaters;" and about seventeen others. It may be affirmed, however, of his Engravings as well as of his Paintings, that his most admirable productions are portraits. In execution they are among the happiest efforts of the Art, and in characteristic expression are unrivalled. Among his numerous pupils, *John George van Uliet*, born at Delft in 1610, has left several Prints in the same style, which have been much sought after notwithstanding defective drawing and clumsy draperies. His practice was to etch his Plates with a very delicate point, and afterwards, by rebiting, and the use of the graver, to strengthen such parts as required. *John Lievens* of Leyden, a pupil of Rembrandt's reputed instructor, Peter Lastman, was no less celebrated as an Engraver than as a Painter of History. Among his portraits, to the number of about sixty, are some excellent compositions, executed in the style of Rembrandt, but somewhat coarsely, as Lievens made no use of the dry point. His "Raising of Lazarus" is thought a superior composition to Rembrandt's, and is equally well engraved. *Ferdinand Bol*, (Painting, p. 483.) born at Dort in 1610, having settled in early youth with his family at Amsterdam, attended there the School of Rembrandt. His etchings evince great merit, and most judicious management of light and shade, but want the playful airiness which belongs to the touches of Rembrandt. *Simon Vlieger*, a contemporary landscape-painter of Amsterdam, who taught the younger Vandevelde, (Painting, 484.) etched some spirited views, adopting the style of Rembrandt. *Solomon Koninck*, born in 1609 at Amsterdam, is another successful imitator, both on canvas and on copper, of his great contemporary. He learned Painting under Nicholas Mojaert, but appears to have formed his style from an attentive study of the small Pictures by Rembrandt. His compositions are excellent, and are executed with all the richness and clearness of his prototype. Other pupils of Mojaert were likewise Etchers, *Jacob Vanderdoes the elder*, (*Peintre Graveur*, vol. iv. p. 189.) and the *elder Weeninx*, (*Ibid.* vol. i. p. 389. and see Painting, p. 484.) but in a different style. Their etched landscapes with cattle and animals have the masterly air of their painted Works. *Marc de Bye*, a disciple of Vanderdoes, followed his master with less celebrity as a Painter than as the producer of some excellent etchings of animals after Paul Potter and Marc Gerard.

Artists' Names.	Where born and when.		Died at	A. D.
Adrian van Ostade,*	Lubeck	1610.		1685
Reiner Nooms, alias Reiner Zeeman,†	Amsterdam	1612		
Anthony Waterloo,‡	Utrecht or Amsterdam about	1618		
Hermann Swanevelt,§	Woerden	1620	Rome	1690
*Nicholas Berghem**	Haerlem	1624		1683
Paul Potter†	Enkhuysen	1625		1654
Carl du Jardin‡	Amsterdam	1635	Venice	1678

* (See Painting, p. 483.) *Ostade* merits a place next to Rembrandt for profound delineation of character, and of character really adapted to the scenes he portrays. His personages, like Rembrandt's, are drawn from the haunts of gross vulgarity; but are not made to act "high life below stairs," nor forced *pêle mêle*, like Rembrandt's, into the sublimer walks of Historic Painting. They retain, under Ostade's management, their proper station. His etchings, amounting to upwards of fifty, are in great and well-deserved estimation. *Cornelius Bega* and *Cornelius Dusart*, both of Haerlem, were disciples of A. van Ostade, and painted in the same style. By the former of the two we have about five and thirty excellent Plates of cottage interiors, boors regaling, &c.; and by the latter a number of similar etchings, also very spirited; together with a few Works in mezzotinto. (*Peintre Graveur*, tom. v. p. 221, 463.)

† *Renier Zeeman*, (seaman,) so styled for his sea pieces. His shipping and figures in these marine Paintings are admirably drawn and spiritedly touched. The same praise is due to his etchings, and we only lament that such minute correctness, as well as freedom of hand, should be confined to the monotony of Dutch portraiture.

‡ *Waterloo* is the glory of the Dutch School in this kind of Engraving. His Paintings are rare gems of Art, and their scarcity arises partly from his having engraved so much; and partly, it is said, from habits of intemperance, to which he fell a victim in the prime of life. His Works, as Mr. Gilpin justly remarks, do not display much variety, nor seem to have cost him much stretch of fancy. "He selects a few striking objects; a coppice, a corner of a forest, a winding road, or a straggling village is generally the extent of his view; nor does he always introduce an offskip. His composition is generally good, and his light often well distributed; but his chief merit lies in execution, in which he is a consummate master. Every object that he touches has the character of nature." His etchings consist of about one hundred and fifty views after designs of his own. (*Peintre Graveur*, vol. ii. p. 1.) No Works of graphic Art have perhaps been more instructive to artists than those of Waterloo. He combined with the utmost spirit and facility of handling a marked attention in the foliage of his trees and plants to their several species. In trees he is probably without a rival. "His only defect," observes the author of the *Catalogue of an Amateur*, "seems to be want of management in the chiaroscuro, as his lights are occasionally too scattered. Having bitten in his plates delicately, he never repeated this operation with the aquafortis, but by stopping out in some cases with a judgment peculiar to himself, he attained the required gradations; and in others, having suffered the aquafortis to bite equally, he arranged and perfected the harmony of his Plates, and added the strongest shadows with the burin. In consequence of this process, however, when his Plates began to wear, the delicate etching soon disappeared, leaving only the coarse work of the burin; and such impressions are improperly considered as retouched. Good impressions of his Works are scarce."

§ *Swanevelt*, like his master, Claude Lorraine, (Painting, p. 483–485.) was a diligent observer of nature and of Italian nature. His studious and solitary walks for this purpose among the ruins of Tivoli and Frescati procured him the name of *hermann* or hermit. He etched in the manner of Waterloo, but with less freedom. His trees, says Mr. Gilpin, bear no comparison with Waterloo's; but he adds another material point of difference in which Swanevelt is far superior, namely, dignity of design. Waterloo saw nature only with a Dutchman's eye, and seldom quitted the plain simplicity of a Flemish scene. But Swanevelt had imbibed ideas of grandeur and beauty from the classic fields, and skies, and mountains of Italy. His engraved Works consist of one hundred and fourteen pieces. *Il avoit une manière de graver*, observes M. Bartsch, *qui lui étoit particulière, et a exprimé les feuilles de ses arbres par un assemblage de petits traits horizontaux un peu courbés qui sont très propres à représenter la situation naturelle sur les branches. Il n'a tracé des contours plus déterminés que quand il en a eu besoin pour dégager les parties.* (*Peintre Graveur*, tom. ii. p. 250.) His pupil and brother-in-law, *James Rousseau*, (Art. 57.) a French refugee Protestant, dismissed for his *heresy* from the Academy of Paris, and expatriated on the Revocation of the Edict of Nantz, retired to Holland. Rousseau was a Painter of considerable merit, and made a visit from Holland to this Country at the invitation of the Duke of Montague, who employed him, in conjunction with Charles de la Fosse (Painting, p. 492.) and J. B. Monnoyer, (*Ibid.*) to decorate Montague House, now the British Museum. He afterwards painted landscapes for the Palace at Hampton Court. His Plates are not numerous, but are beautiful, and etched with great spirit. Another landscape-painter, whose trees are admirably managed, is *Adrian Vander Cabell*, born near the Hague in 1631. His subjects, like those of Swanevelt, are quite anti-Dutch or anti-Belgian, and his style has been thought sometimes to resemble Castiglione, (Art. 51.) and sometimes Salvator Rosa. (*Ibid.*) His figures are correctly drawn, and his animals touched with great spirit. In shipping and marine subjects he had been preceded by Zeeman, and in architectural by Nieulant, Breemberg, and others.

Naiwynx, born at Utrecht in 1620, may be noticed here. He was a landscape-painter in the style of Waterloo. His few etchings are charmingly picturesque and highly valued. Another follower of Waterloo in landscape was *John Hackaert* of Amsterdam, who, like Swanevelt and others, was not satisfied with the contracted scenery of Holland, but delighted in wild woods and mountain torrents. He visited the most romantic parts of Swisserland and Germany; and on one occasion, says M. Bartsch, was seized as a conjuror, and dragged before the chief magistrate at Zurich by some simple natives, who mistook the lines of his sketch-book for characters of magic. (*Peintre Graveur*, vol. iv. p. 77.)

* He was for some time instructed in Painting by the elder Weeninx, (Painting, p. 484–488.) but had previously been a scholar of Van Goyan, under whom he obtained from his fellow-pupils the nickname of *Berghem*. The story is, that his father, on some occasion being angry with the youth, came to seek him at his master's, who, to screen the favourite pupil, called out to the others, "*berg hem*"—*hide him*. His etchings, to the number of fifty-three, (of which an account was published by Henry Winter at Amsterdam in 1767,) represent landscapes and cattle, with occasional figures in a style of more finished execution than is usual with Painters. *John* and *Andrew Both*, his contemporaries and rivals in landscape-painting, have left several charming etchings of landscape. They were of Utrecht, and pupils of *Abraham Bloemaert* in that city, already named as a Painter (Painting, p. 481.) and an Engraver in chiaroscuro, (Art. 46.) but who also etched a number of Plates with a bold and masterly point, some in imitation of pen and ink drawings.

Berghem had several meritorious pupils and followers. *Dirk* (Theodoric or Roderic) *Maas* of Haerlem was his pupil, a Painter of some reputation, who in the reign of William III. visited England, and painted the "Battle of the Boyne" for the Earl of Portland. Maas etched with great spirit some few scarce Plates. *John Vander Meer* the younger (*Peintre Graveur*, vol. i. p. 229.) was one of the best scholars of Berghem. He painted landscapes with cattle in the style of his master; and a few beautiful but scarce etchings attest his ability in handling the point. *John Glauber*, (*Ibid.* vol. v. p. 377.) of German extraction, but born at Utrecht in 1646, was another *élève* of Berghem, and became afterwards celebrated at Amsterdam as the friend and coadjutor of *Gerard de Lairesse*, the Flemish Poussin; (Painting, p. 484.) the former painted the highest order of landscape, which the latter adorned with classic figures. Both Glauber and Lairesse have produced several interesting etchings, in which each illustrates his own kind of composition. Among the happiest graphic translators of Nicholas Berghem, Mr. Gilpin distinguishes *John Visscher*, younger brother of Cornelius, (Art. 40.) and Danker Dankerts of Antwerp. But the ablest of Berghem's scholars was *Karel du Jardin*, hereafter mentioned.

† (Painting, p. 484.) *Paul Potter's* indefatigable devotedness to his Art overpowered a naturally feeble constitution, and carried him off at the age of only twenty-nine. His etchings are greatly admired for their execution, and, in general, for their correctness. Mr. Gilpin praises his cows and horses, but regards his sheep as indifferently drawn and inaccurately characterised. *John le Ducq*, who studied Painting under him, and pursued for some time very successfully his style, has left some good etchings: in particular eight Prints of dogs, spiritedly drawn and neatly executed. (*Peintre Graveur*, vol. i. p. 197.)

‡ (Painting, *Ibid.*) The well-known etchings by *Du Jardin*, to the number of fifty-two, with figures and animals, show the same master hand as his admirable Pictures. His taste was decidedly

Artists' Name.	Where born and when.
Romeyn de Hooghe[*]	At the Hague about 1638.

The Prints of the two first of the above-named artists portray similar subjects to those of their Paintings. (PAINTING, p. 482, 483.) The remaining number excelled in Prints of landscape, with animals, trees, figures, buildings, &c., or in marine pieces and seaports with shipping and appropriate accessories. We ought to add that among Painters and Etchers of architectural ruins and historical landscape *William Van Nieulant; Paul Bril*, born at Antwerp in 1584; *Bart. Breemberg*, born at Utrecht 1620; and *Bonaventure van Overbeck*, a supposed scholar of Lairesse, born at Amsterdam in 1660, deserve a distinguished place in the list.

France. Compound Chalcography.

(56.) The FRENCH School in this department is distinguished by many eminent names. The encouragement, indeed, which the Court of France in the XVIIth and following Century bestowed on graphic talent has been well rewarded. A prejudice, however, prevailed among French burinists against etching; and they seem to have surveyed its progress with a jealousy that retarded its introduction into the higher walk of Art, and prevented their deriving advantage from the powerful helps peculiar to the etching point. Several Works of Chaveau, for example, one of the best handlers of the French graver at the most brilliant part of the period alluded to, exhibit the utmost dexterity in the use of his favourite instrument; but would have attained a far superior effect, and have risen to a much more faithful representation of the original Pictures, had he condescended to introduce etching in that portion of his Plates for which it is best adapted.

In the following lists, as well as in our former columns, the reader will perceive how well the Parisian atmosphere[*] was for a long period suited to the cultivation and progress of this difficult and laborious Art. The best Engravers of France were either born at Paris or at Paris they settled, and at Paris they died. To begin with the first class. (Art. 49.)

First class in France.

Artists' Names.	Where born and when.		Died at	A. D.
Etienne Baudet[†]	Paris	1598	Paris	1691
François Chaveau[‡]	Paris	1618	Paris	1676
Gabriel Perelle	Paris about	1620		
Pierre Landry[§]	Paris about	1630		
Guillaume Château[||]	Orleans	1633	Paris	1683
Claudine B. Stella[¶]	Lyons	1634	Paris	1697
Guillaume Vallet	Paris	1634	Paris	1704
Sebastien le Clerc[**]	Metz	1637	Paris	1714

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more Italian than Dutch. To the truth and finish of Paul Potter he adds the graces of a more cultivated imagination. Mr. Gilpin (*Essay on Prints*, p. 132.) institutes a comparison between Du Jardin and *Abraham Hondius*, his contemporary of Rotterdam, and contrasts the sublimely savage and furious animation of the hunting pieces etched by the latter artist with the Arcadian quietness, the refined and pastoral repose of Du Jardin. Hondius, like *John Fyt* of Antwerp, was an excellent Painter of animals. Fyt also etched a few Plates of animals drawn with his accustomed spirit. Antwerp had given birth about fifty years before, in the preceding century, A. D. 1579, to *Francis Snyders*, an eminent Painter of similar subjects, (PAINTING, p. 482.) whose etchings, about sixteen in number, are very interesting specimens in this class. A few etchings likewise of animals by *Albert Cuyp* (PAINTING, *ibid.*) are preserved by the curious, as admirable examples of composition, drawing, and expression. *Peter de Laer*, (*Ibid.* p. 483.) styled *Bamboccio*, from his favourite subjects *bambocciate*, such as fairs, festivals, masques, processions, &c., has executed some bold and masterly etchings of horses and other animals. With true feeling for the Art, Mr. Gilpin laments the want of suitable Engravings after the grand hunting subjects painted by Rubens.

[*] Already noticed in the preceding class, (Art. 54.) he claims a place together with his successful follower, *John Luykin*, (called the Callot of Holland,) among the best etchers of historical landscape. *Albert Van Everdingen* and *Francis de Neve* are worthy of the same rank. Everdingen was an admirable Painter of stormy and rocky scenery, to which talent the accident of his shipwreck on the coast of Norway, and detention for more than a year in that Country, seems to have contributed. He obtained the appellation of the Salvator Rosa of the North. His Prints of landscape, to the number of about one hundred, are fine compositions, but not all equally well executed. He is well known for a series of fifty-seven etchings, illustrating the "History of the Fox," a satirical Poem imputed to Henry Von Alkmaar, for an account of which see Roscoe's *German Novelists*, ed. 1826. *Ludolph Backhuysen*, a pupil of Everdingen, also painted sea storms with splendid success, and has left some Plates with views of shipping on the Y, a small arm of the sea near Amsterdam. He died in 1709. De Neve, the contemporary of Everdingen, was born at Antwerp in 1627, where he studied the Works of Rubens and Vandyke, and afterwards resided and studied some years at Rome. He painted and etched with great fertility of genius and fine taste. *Avec toute l'élégance*, says M. Bartsch, *du stile noble de l'école d'Italie*. His Prints consist of forty landscapes, into which fabulous characters are introduced. Of Luyken, born at Amsterdam A. D. 1649, it is observed that he resembles Callot rather in the infinite crowds of figures which cover his Prints than in the neatness or spirit of his etching point. But his Plates have great merit, though not equal to the master touches of De Hooghe. Among the Dutch imitators of Callot, *Peter Quast*, of the Hague, his contemporary, deserves creditable mention.

[*] Engraving seems at one time to have been a fashionable accomplishment at the Court of France. Pompadour, Louis XVth's Marchioness, amused herself with this Art, and executed several Plates after Boucher, Eisen, and others. She also engraved a set of sixty-three Prints after gems by Gay.

[†] The early works of *Baudet*, and of several others in this list, are executed with the burin only. In their future and more successful efforts they called in the assistance of the etching point. Baudet's former attempts seem in the style of Cornelius Bloemaert; (Art. 40.) his later productions, at his return to Paris from Rome, where he studied, bear a strong resemblance to the manner of *J. B. de Poilly*, of whom, however, he could not have been an imitator, as De Poilly must have been a child when Baudet's best Prints were well known.

[‡] *Chaveau*, likewise, quitted the sole use of the graver to introduce the etching point. His Works betray haste, but are full of spirit and force. Nearly three thousand Prints are from his hand, chiefly for booksellers. His best are some small Plates in the style of Sebastien le Clerc. He had studied Painting under Laurent de la Hire, (PAINTING, p. 490.) and painted small Pictures in the style of that master.

Gabrielle Perelle ranks high among the landscape Engravers of France. His Works, in which he was assisted by his sons, *Adam* and *Nicolas*, are very numerous, both from designs of his own and from those of Paul Brill, Gaspar Poussin, Asselyn, and Silvestre. There is a satirical Print, by the Perelles, from a design of Richer, caricaturing the surrender of Arras to the French in 1642. The citizens had inscribed on their gates,

Quand les François prendront Arras
Les souris mangeront les chats.

Their enemies, however, took the place, and only erased the letter *p* from the inscription.

[§] Some portraits by *Landry* have merit. He was much employed by booksellers.

[||] A pupil at Rome of J. F. Greuter. The Prints by *Château*, in which he introduced the point, are excellent. His early style resembles that of Bloemaert. He enjoyed till his death the patronage of Colbert at Paris. *Benoit Trajat*, born at Lyons in 1646, was a scholar of Château, whom he surpassed in freedom of touch, neatness, and mellowness, though not in other respects. Frajat settled at Rome.

[¶] The Prints by this female artist, after the designs of her uncle and preceptor Jacques Stella, (PAINTING, p. 490.) and of his friend Nicholas Poussin, are very fine. Probably no Engravings after Poussin have been more successful. Her uncle *Jacques*, a Painter, highly patronized by Richelieu, has left some etchings. Her sisters, *Antoinette* and *Françoise*, were likewise excellent etchers.

[**] This is another native of Lorraine, whose Works, like those of his fellow-countryman Callot, are of great *numerical* extent and deserved celebrity. Nearly three thousand Plates are from the hand of *Le Clerc*. But then, as Mr. Gilpin observes, his limits seldom exceed six inches; and within these limits he can draw up with admirable dexterity twenty thousand men, and confer immortality in miniature on Alexander and Louis XIV. He advanced his Engravings considerably with the etching point. Grace and

Chalcography.

Artists' Names.	Where born and when.		Died at	A. D.
Charles Simonneau	Lyons	1639	Paris	1728
Louis de Châtillon.	St. Menehould, in Champagne	1639	Paris	1734
Germain Audran	Lyons	1631	Paris	1710
*Gerard Audran**	Lyons	1640	Paris	1703
Jean Audran	Lyons	1667	Paris	1756
Benoit Audran	Lyons	1661	Paris	1721
Nicolas Dorigny†	Paris	1657	Paris	1764
Antoine Coypel	Paris	1661	Paris	1722
Gasper Duchange	Paris	1662	Paris	1759
*Jean Bapt. de Poilly**	Paris	1669	Paris	1728
Nicolas Henri Tardieu	Paris	1674		
Jacques Nicolas Tardieu	Paris	1718		
Claude Duflos†	Paris	1678	Paris	1747
Louis Desplaoes	Paris	1682		
Nicolas du Larmessin the younger‡	Paris	1684		
Charles Dupuis	Paris	1685	Paris	1743
Nicolas Gabriel Dupuis	Paris	1696	Paris	1770
Frederic Hortimels§	Paris	1688		
Bernard Lepicié	Paris	1699	Paris	1755
Jean Jacques Flipart ‖	Paris	1723		
Laurent Cars¶	Lyons	1702	Paris	1771
Jacques Philippe le Bas	Paris	1708	Paris	1782
Jacques Firmin Beauvarlet	Abbeville	1733		
Jacques Aliamet	Abbeville	1727	Paris	1788
François Aliamet	Abbeville	1734		
Pierre le Pautre	Paris	1744		

France. Second class as composed Chalcography.

(57.) In the second and more numerous class some of the above names might be repeated; and some, such as Le Clerc and others, may perhaps be considered out of place in class the first. (Art. 56.) But besides that the precise degree in which etching combines with the burin is, in most of the works now under our consideration, by no means easily determinable, our space has not permitted us to make more than a very general arrangement.

Early French artists.

We have had occasion to mention among the Wood-Engravers of France *Jacques Perisin*, or *Persinus*, as he sometimes inscribed himself. He executed some Plates coarsely etched and not correctly drawn, in concert with his contemporary *J. Tortorel*, representing the Wars of the Hugonots. The Work of these artists, who flourished about A. D. 1570, is only remarkable as exhibiting the earliest specimens recorded of etching among French artists, although the process had been almost half a century in use among their neighbours. There is, however, a spirited etching of this period, "The Departure of Hagar and Ishmael," by *René Boivin*, who was also a burinist, born at Angers about A. D. 1530. *Antoine Garnier* was one of the Engravers at Fontainebleau, (Art. 51.) after the Paintings by Prima-

Boivin.

Garnier.

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elegance in the forms, and noble expression in the heads of his figures, distinguish this artist: and where landscape with buildings or other accessories is introduced, his tasteful arrangement and execution charm every eye; though in lightness and playful management of the point Della Bella is considered his superior, (Art. 51.) and his stroke is pronounced by Mr. Gilpin to be not so firm nor so masterly as that of Callot. Le Clerc was likewise an engineer, an architect, and a mathematician. His father, a goldsmith, intended him for a military life, and with the hope of a commission for him in the French service sent him to Paris, where, by the advice of Le Brun, and under the liberal patronage of Colbert, he became one of the most successful in his class of Art.

* This artist contributed to immortalize Le Brun by his admirable "Battles of Alexander." This superb set of Prints is completed by a Plate from the hand of Gerard Edelinck, "Alexander entering the Tent of Darius." In large Plates of historical subjects no Engraver in this class has been more distinguished than *G. Audran*. He was the son of Claude Audran, (Art. 41.) and nephew of Charles. (*Ibid.*) His brother *Germain* was of inferior merit, but his nephews *Benoit* and *Jean*, sons of Germain, profited largely from his instructions. *Charles* and *Louis Simonneau* and *Louis de Châtillon* formed themselves by the study and imitation of the fine style of Audran. Charles Simonneau was a pupil of Château, and at first worked in the manner of Francis de Poilly with the graver only; but afterwards introduced the point into his demitints and distances, reserving the graver for such parts as required prominency and vigour.

A good many of the artists in the above list were pupils or followers of the Gerard Audran School. On the merits of *Antoine Coypel* as a Painter we have already made some remarks, (PAINTING, p. 492.) in which M. Watelet's judgment concurs with our own, and condemns the practice of *Frenchifying* the heroes of antiquity. We wish we could call our own artists altogether free from the use of English physiognomy on similar subjects. A. Coypel etched several of his own designs. Mr. Gilpin praises an "Ecce Homo" by this artist, which, as well as some others, was finished by Simonneau. *Du Change* resembles Jean Audran. His Plates after Coreggio are worthy of that Painter. *Charles Dupuis*, his pupil, combined, in like manner, mellowness and harmony of execution with admirable drawing and heads full of expression and character. *Nicolas Gabriel Dupuis*, the other brother of that name, was also a pupil of Jean Audran. *N. Henri Tardieu* was a scholar of P. le Pautre, and afterwards of Jean Audran. His son *Jacques N. Tardieu* used more of the graver and less of the point than his father, to whom he is inferior, though an artist of considerable merit. *Jacques P. le Bas* was his fellow-pupil under N. H. Tardieu, and excelled in landscapes with small figures, which are beautifully touched, etched with great fire and spirit, and then harmonized with the graver and dry point. *Louis Desplaces* adopted in several of his numerous Plates (the best of them after Jouvenet) the style of Gerard Audran. *Jacques Aliamet* was a pupil of Le Bas, and distinguished himself by several good Plates of landscape after Vernet. His brother, *François Aliamet*, was for some time under Sir Robert Strange in London. *Bernard Lepicié* was a respectable artist, though not very correct draughtsman, and is regarded as a successful imitator of Jean Audran, whose pupil he probably was. His wife *Renée Elizabet* was also a neat Engraver. Fine specimens from most of these artists of the Audran School are to be found among the Engravings for the Crozat collection.

† The family of *Dorigny* is conspicuous in graphic biography. The father, *Michel*, born at St. Quentin in 1617, studied Painting under Vouet, and his son *Louis* under Le Brun. Michel is better known as an Engraver, but his Work is heavy from being overcharged with the burin; and Louis, who lived and painted chiefly and with some reputation in Italy, and died at Verona in 1742, has left several free painter-like etchings. Sir Nicolas, a younger son of Michel, knighted by George I. on the occasion of engraving the Cartoons of Raffaelle, resided thirteen years in England. He did not succeed in Painting, for the study of which he quitted at thirty the profession of the Bar; but his later and best style as an Engraver, modelled after that of Gerard Audran, to whom, however, he was much inferior, obtained him great and deserved reputation. The particulars of his history, some of them collected by Vertue from his own mouth, will be found in Walpole, *Catalogue of English Engravers*, p. 207.

* This was the son and pupil of Nicolas de Poilly. (Art. 41.) but his style differs remarkably from his father. His Plates, both in history and portrait, are specimens of good drawing and fine expression. A pupil of his, *Peter Aveline*, born at Paris in 1710, had considerable talent, which would have been more conspicuous if more of the subjects had been better chosen, and not sketchy trifles.

† *Duflos* resembles François de Poilly, (Art. 41.) but occasionally called in the assistance of the point. There is great neatness and finish in his numerous Prints.

‡ A pupil and son of the burinist Nicolas Larmessin the elder. (Art. 41.) His Engravings for the Crozat collection gained him great celebrity, but his Works deserve not to be quoted for design nor for effect.

§ The Plates by *Hortimels*, in this class, have considerable merit. His best are for the Crozat collection. His daughter, *Maria Madeleine*, the wife of Charles Nicolas Cochin, engraved several Plates in the style of her husband, who, in 1758, published reflections on the Paintings and Sculptures of different European cities he had visited: a Work very favourably received.

‖ He greatly surpassed his father and instructor Jean Charles Flipart, the burinist, (Art. 41.) and produced by a union of etching with Engraving many estimable Works.

¶ *Cars* ranks as one of the best Engravers in the XVIIIth Century for the kind of subjects, both in history and portrait, after Rigaud, Vanloo, Le Moine, Boucher, Watteau, and other designers which he selected. His "Hercules and Omphale," after Le Moine, is a *chef-d'œuvre.*

Perrier.

ticcio. He flourished at Paris about A. D. 1560. *François Perrier*, born at Maçon in Burgundy, who studied in Italy, and Italianized his name to *Paria*, was a Painter of some celebrity, (PAINTING, p. 490.) and has left etchings in the manner of Palma, which Mr. Gilpin looks upon as successful imitations of that master; but they are slight and hasty performances, and often incorrectly drawn. He died at Paris in 1660.

Vignon

Claude Vignon, born at Tours in 1590, is another Painter who has left some specimens of masterly etching. Simon Guillam, a French Sculptor of about the same date, etched for his amusement several plates in a very spirited style.

Brebiette. Chaperon.

Pierre Brebiette and *Nicolas Chaperon* were provincial artists, born in 1596, who established themselves at Paris. The former, whose Paintings are little known in this Country, etched with considerable ability some clever designs from his own pencil. The latter was a pupil of Vouet, but made no progress, and afterwards at Rome betook himself to engraving the Pictures in the Vatican called "Raffaelle's Bible." It is recorded to the credit of this performance, that his work is, perhaps, the least faulty of the numerous graphic transcripts from those invaluable Paintings.

Other subsequent names.

The names that follow belong to the XVIIth and subsequent Centuries:

Artists' Names.	Where born and when.		Died at	A.D.
*Jacques Blanchard**	Paris	1600	Paris	1633
Michel Corneille the elder†	Orleans	1603	Paris	1664
Henri Mauperché	Paris	1606	Paris	1686
Laurent de la Hire	Paris	1606		
Israel Henriet	Naucy	1607	Paris	1661
Nicolas Mignard	Troyes in Champagne	1608	Paris	1668
Peter Mignard	Ditto	1610	Paris	1695
Abraham Bosse‡	Tours	1610	Paris	1698
Jacques Bellange	Chalons, about	1610	....	1642
Claude Dervet	Nancy in Lorraine	1611		
*Jean Morin**	Paris, about	1612	Paris	1666
J. R. de St. André	Paris	1614	Paris	1677
Samuel Bernard	Paris	1615	Paris	1687
Louis Testelin	Paris	1615	Paris	1655
Sebastian Bourdon†	Montpelier	1616	Paris	1671
Jean le Pautre	Paris	1617	Paris	1682
Charles le Brun	Paris	1619	Paris	1690
Nicolas Cochin	Troyes in Champagne	1619	About	1700
Jacques Courtois, alias *Bourguignon*	St. Hyppolyte in Franche Compté	1621	Rome	1676
Israel Silvestre	Nancy	1621		
Alexandre Silvestre	Flourished about	1700		
François Colignon	Nancy, about	1621		
Domenique Barriere	Marseilles	1622		
Jean Pesne (*Il Penna*)	Rouen	1623	Paris	1700
Nicolas Loir	Paris	1624	Paris	1679
Alexis Loir	Paris	1630		
Etienne Gautril	Paris	1626		
Jacques Rousseau‡	Paris	1626		
Noel Coypel	Paris	1628	Paris	1707

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* Several distinguished Painters of the French School were excellent Etchers, and many names in this list will be found in our former pages; as *Jacques Blanchard*, (PAINTING, p. 490.) *Sebastian Bourdon* and *Charles le Brun*, (*Ibid.* p. 491.) *Nicolas Mignard*, *Jean le Pautre*, father of Pierre, (Art. 56.) *Jacques Courtois*, or *Bourguignon*, *Raymond de la Fage*, *Joseph Parrocel*, *Antoine Watteau*, and *Pierre Subleyras*. (*Ibid.* p. 492.)

† The elder *Michel Corneille* was a pupil of Simon Vouet, (PAINTING, p. 490.) in whose style he executed several Paintings for Churches. He was one of the original twelve Members of the Royal Academy at Paris. His son, *Michel the younger*, had the advantage of the King's pension to enable him at Rome to complete his studies, which he prosecuted with becoming industry and energy. He was much employed by Louis XIV. Both artists left many fine etchings after Raffaelle, the Caracci, and their own designs. The name of Raffaelle was affixed by a cunning printseller at Rome to a set of Plates designed by the younger Michel Corneille. *Jean Bapt. Corneille*, his brother, born at Paris A. D. 1646, was also a Painter of some reputation, but inferior to Michel. He also etched with great spirit several Plates from his own designs and after the Caracci. Claude Gillot was his pupil, and Watteau a scholar of Gillot.

Another pupil of Vouet may be mentioned here, *Pierre Mignard*, who relinquished for the instruction of that able master the profession of Medicine. He then studied Painting at Rome for twenty-two years, and was much patronised by Urban VIII. and succeeding Popes, Both he and his brother Nicolas were too much engaged in designing to engrave more than a few Plates. They are bold, painter-like etchings. The family name and origin, says Watelet, were English. Some fine young Englishmen named More, serving in the army of Henri Quatre, were presented to that Monarch, who observed, *Ces ne sont pas des* Mores (negroes) *mais des* mignards (handsome fellows.) *Jacques Bellange* was also a scholar of Vouet. His Engravings have the merit of tolerable execution and excellent chiaroscuro, but his drawing of heads and figures is, as Mr. Gilpin observes, affected and bad. *Samuel Bernard* and *Louis Testelin* were likewise under Vouet.

‡ Author of a Treatise entitled *La Manière de graver à l'Eau forte*, republished afterwards by Cochin with additions. Bosse worked chiefly from his own designs, but among his Prints, which are numerous, will be found many after other masters. His style is free and spirited, and finished with the graver in a masterly manner. His instructor in the Art is unknown, but he seems to have taken Callot for his model in those Plates on which the latter bestowed less finish.

There are in this list several other imitators of Callot (Art. 51.) who may here be mentioned. *François Colignon* was instructed in the Art by Callot. *Claude Dervet*, who was a pupil of Claude Henriet, a Painter little known, lived in habits of intimacy with Callot their fellow-countryman, and adopted the style of his friend. *Israel Henriet*, the son of Claude Henriet, studied some time at Rome under A. Tempesta, but was imitator of Callot. He became a printseller at Paris, and published his own Plates as well as those of Callot, Della Bella, and Israel Silvestre, to all of whom he occasionally gave employment. Another scholar of Claude Henriet was *Israel Silvestre*, who formed his style from the study of Della Bella and Callot, and seems, in his turn, to have been sometimes followed by Le Clerc. (Art. 56.) His son, *Alexandre Silvestre*, produced some good Prints, though inferior to those of Israel.

Nicholas Cochin was another follower of Callot, of whom he is supposed to have been a pupil. Like his master, he succeeded better in small figures than in those of larger dimensions.

* The best Prints of *Morin* are his portraits, and these are admirable productions. His Cardinal Bentivoglio, after Vandyke, is worthy of that inimitable Picture. His execution is peculiar. He stippled his heads with the graver, intermixing lines and dots so harmonized as to produce a very pleasing effect. His Works extend, says M. Bartsch, to one hundred and twelve Plates. He had been a pupil of Philippe de Champagne, (PAINTING, p. 492.) but abandoned Painting for Engraving.

† *Bourdon's* Plates, which are numerous, and etched with a masterly point, are precious to every collector. They give a perfect idea of his manner of Painting. A kind of union, in landscape, of Titian with Poussin, picturesque backgrounds, and judicious management of light and shadow are the characteristics of this artist. It is to be regretted that his drawing is often faulty. Two of his pupils, *Nicolas Loir* and *Jacques Prou*, are in the above list. The etchings of N. Loir, to the number of nearly one hundred and fifty, are slight but spirited. His brother *Alexis* was an Engraver of considerable merit, after Rubens, Le Brun, Mignard, N. Poussin, Jouvenet, and his brother's designs. Their father was a goldsmith.

‡ *Rousseau* was a refugee Protestant who fled to England from the Persecution under Louis XIV. at the time of the Revocation of the Edict of Nantz. He married a sister of Herman Swanevelt (Art. 55.) and profited by his instructions. Under the patronage in England of the Duke of Montague, Rousseau contributed to the decoration of Montague House with his paintings. Mr. Gilpin, after remarking on his faults as an artist, subjoins that he was an excellent man. "Having escaped the rage of Persecution himself, he made it his study to lessen the sufferings of his distressed brethren by distributing among them the greatest part of his gains. Such an anecdote, he adds, should not be omitted in the life of a Painter, even in a short review of it." His etchings are beautiful.

Artists' Names.	Where born and when.		Died at	A. D.
Jacques Prou	Paris	1639		
*Jean Dolivar**	Saragoza	1641	Settled at Paris.	
Michel Corneille the younger	Paris	1642	Paris	1708
Jean Bapt. Corneille	Paris	1648	Paris	1695
Joseph Parrocel†	Brignoles in Provence	1648	Paris	1704
Raimond de la Fage	Toulouse	1648	Paris	1690
Brothers *Bon Boullogne*‡	Paris	1640	Paris	1717
Louis Boullogne	Paris	1654	Paris	1734
Bernard Picart§	Paris	1663	Amst.	1733
J. Bapt. Boyer (Marquis d'Aiguilles)	Aix	1666		
Antoine Trouvain	Montdidier	1666		
Antoine Rivalz‖	Toulouse	1667	....	1735
Claude Gillot	Langres	1673		
Antoine Watteau	Valenciennes	1684	....	1721
Chas. Nicolas Cochin the elder	Paris	1688		
Pierre Subleyras	Usez in Languedoc	1699	Rome	1744
Nicolas Chas. Silvestre¶	Paris	1700	Paris	1767
Quentin Pierre Chedel	Chalons	1705	....	1762
Chas. Nicolas Cochin the younger**	Paris	1715		
Bartholomew Rivalz	Toulouse	1724		
Jean Jacques de Boissieu††	Lyons	1736	Paris	1805

Chalcography. Spain.

Academy of San Fernando.

Carmona.

Palomino.

(57.) Out of the names of SPANISH Chalcographers given in a preceding Note (Art. 42.) (Note (Z.) at the end of ENGRAVING) we had intended to select some for particular observation here. But we must confine ourselves to a quotation from D. Cean Bermudez in his account of the establishment at Madrid of the Academy of San Fernando. It is to be found under the name Olivieri, in the *Diccionario dellas Bellas Artes*. "The art of copper-plate Engraving in Spain may be truly said to date its rise from the Academy of San Fernando. The fathers of the Art in that Country were Directors of the Academy.* It is true that the appointment of Engraver to the King's Cabinet had been previously held by meritorious artists, but their manner of executing copper-plate was more the result of their own genius than of any received principles of their Art. The first teacher of the elements of Engraving was *D. Manuel Salvador Carmona*,† one of the students under an Association preparatory to the foundation of the Academy, who was sent to Paris with a pension from the King to learn Engraving. At the same time, and with the same encouragement, *D. Juan de la Cruz* and *D. Tomas Lopez* were at Paris learning to engrave architecture, geographical maps, and ornamental Plates. Besides efforts abroad, the Academy received every possible benefit from one of its Directors, *D. Juan Barnabe Palomino*, who, without quitting Spain, had acquired for himself the Art of Engraving in a style which combines correctness with great clearness and lightness. He distributed to each of three pupils out of the number under his tuition an annual prize of one hundred and fifty ducats, to be conferred after a fair competition among the candidates; and he added, in 1760, a general premium, according to the advancement of the Art in its application to Works of Painting, Architecture, and Sculpture. Lastly, that no advantage should be wanting to give full effect to these arrangements, and to the

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* *Dolivar* has been ranked with Chaveau and Le Pautre, but is inferior to both.

† *Parrocel* painted battles for Louis XIV. His best etchings are some small Plates of battle-pieces very scarce. A free, bold, and masterly style, and an admirable knowledge of chiaroscuro, pervade his productions. His "Life of Christ," in a series of numerous Plates, is considered inferior to his other Works. There lived in the following century another Parrocel, *Etienne*, probably of the same family, who executed some spirited etchings after De Troy, Subleyras, and others. Joseph Parrocel had been preceded in battle-painting by the famous *Jacques Courtois*, surnamed *Bourguignon*, (PAINTING, p. 492.) whose style he seems to have studied. Courtois has left some etchings of battles executed with masterly skill and effect. His custom of attending the army, and sketching on the spot during skirmishes and sieges, obtained him great facility. His name, Italianized in Italy to *Cortese*, or *Il Borgognone*, is well known by many splendid effusions of his pencil in that Country.

‡ The *Boullognes* were pupils of their father, the elder *Louis Boullogne*, Historical Painter and Professor in the Academy at Paris, by means of which his sons were sent to Rome and became Painters of considerable eminence. *Bon* was celebrated for pasticcio painting, and his brother *Louis* for a more vigorous tone of colour than generally prevails in the French School. There are several historical etchings by the sons and three by the father, one of them after Guido.

§ We have already noticed the *Picarts* under the School of De Poilly. (See sixth Note to Art. 41.) They have left numerous etchings among their engraved Works. Those of *Bernard* are chiefly book Plates. *Antoine Trouvain* pursued the style of Bernard Picart.

‖ *Rivalz* was a follower of La Fage, and has left many spirited etchings as well as drawings in the style of that master. Of La Fage's drawings, Carlo Maratti, with whom he was intimate at Rome, observed with characteristic enthusiasm, that he (Maratti) would abandon the Art if La Fage's Painting equalled La Fage's drawing. Many of La Fage's beautiful designs, some of which he etched himself, are engraved by Audran, Vermeulen, Simonneau, Ertinger, and others. *Bartholomew Rivalz* was a nephew and pupil of Antoine Rivalz.

¶ Grandson, according to Basan, of Israel Silvestre before-named. *Susannah Silvestre*, a lady of the same family, engraved some heads and portraits after Vandyke.

** *Charles Nicolas*, the father, abandoned Painting at the age of nineteen for Engraving, and has left many graphic specimens of taste, spirit, and correctness. He is most successful in figures of a middle size. The Plates of Charles Nicolas, the son, extend to upwards of fifteen hundred, many of them vignettes, frontispieces, &c., but the latter are so well executed as to have been sufficient to establish his fame.

†† Four Prints by this admirable artist are mentioned in the *Catalogue of an Amateur*, three landscapes and one interior in the style of Rembrandt. His friends designed him for the profession of the Law, but he devoted himself to Painting and Engraving, chiefly to the latter.

* Under the auspices of Philip V., who, from the moment of his accession to the throne of Spain, applied himself with laudable anxiety to the revival of the Arts in that Country, by inviting to his Court several distinguished foreigners from France and Italy. One of these was D. Juan Domingo Olivieri, a Genoese sculptor, who, by the success of his School at Madrid, showed the practicability of establishing a Royal Institution. At his instance, the King, in 1744, gave his sanction for that purpose, and assigned as an appropriate edifice the Casa de la Panadaria. The death of Philip, however, in 1746, suspended for a time the completion of the establishment, but his son and successor Fernando, (Ferdinand V.) whose name the Academy bears, completed the undertaking with truly Royal munificence. Charles III. was a further contributor to its advancement, and among other privileges he granted, in 1778, to the Professors of San Fernando the honour of ranking with the Noblesse and Gentry of Spain. His son Charles IV. took great interest in the proceedings of the Academy, and himself frequently presided for the distribution of premiums.

Among the foreign artists invited to the Court of Spain was the family of Trepolo already mentioned. (Art. 51)

† This eminent Engraver was born at Madrid in 1740. He was a pupil at Paris of Charles Dupuis, (Art. 56.) and was received into the Academy of Paris in 1761. His Prints after Solimeni, Velasquez, Murillo, Vandyke, Guercino, Mengs, and others, are very fine. His pupil, *Fernando Selma*, engraved some admirable Plates in the same style after Raffaelle. Among the few Spanish Painters who have excelled in the use of the etching point, *D. Vicente Victoria* ought to be mentioned, born at Valentia in 1658. He enriched the Cathedral of his native city with several fine Pictures. He was a man of taste and erudition, a Canon of S. Felipe, a distinguished antiquary, an acute writer on the Art, and a celebrated Poet, the intimate of Palomino, and of most of the able men of his time, both in Italy and in his native Country. Bermudez mentions a Work by him, *Historia Pictorica*, the publication of which was prevented by his death at Rome in 1712. He was a scholar of Carlo Maratti.

progress of the students, two of the Academy were in 1763 sent to Paris with a pension from the King, to learn the mode of printing from copper-plate and of preparing and manufacturing every requisite for this important and long neglected object."

England.
Artists in compound Xylography.

(58.) Approaching the ENGLISH School in that department of the Art for which our Countrymen have been most celebrated, we are bound in honesty to remark, that however successfully native genius and energy have brought the united exercise of the point and graver to a degree of excellence never surpassed, we are much indebted to foreign aid for the foundations of our graphic fame. We have already noticed (Art. 43.) that no Works with the burin only have been executed in England that will bear comparison with the *chefs-d'œuvre* of our Gallic and Flemish neighbours. Some British critics, indeed, have in former times, with a very natural and by no means unpardonable patriotism, withheld this acknowledgment, but the British School of Engraving may now very well afford to make it.[*] As it was truly observed, during the last long war with France, that most of our best ships were taken from our maritime rivals, so may it be as truly affirmed with respect to the laborious and ingenious productions now before us, that the industry and talent of Great Britain have profited by the progress of foreign Engravers, and with honourable rivalry have not only made the labours of foreign hands their own, but have improved upon the inventions of their competitors. Our following list in the first class (Art. 49.) was much longer, and included at least eighty names, but brevity constrains us to mention only the leading artists.

Very numerous, and eminently successful.
First class. (Art. 49.)

Artist's Name.	Where born and when.		Died at	A. D.
Wenceslaus Hollar[†]	Prague	1607	London	1677
William Faithorne the elder[*]	London		London	1691
David Loggan[†]	Dantzic, about	1630		

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[*] Evelyn, in his *Sculptura*, (p. 91.) compares *Thomas Cecil*, an artist certainly of some merit, to the best Engravers of his time—the time of Nanteuil! (Art. 41.) Also *William Lightfoot*, of whom as an Engraver nothing is known, and who was employed as an architect at the building of the Royal Exchange, Evelyn considers *little inferior to Wierinx*. (Art. 40.) In a subsequent reign too, the reign of Pope and Addison, and literary taste, we wonder how those lights of our Augustan Age in England could lavish such injudicious praise on mediocrity in the Fine Arts. The Works of *Isaac Fuller*, who has left some very indifferent etchings, and whose portrait-painting was his only merit, called forth an Addisonian Poem in Latin: and *Charles Jervas*, who it is said instructed Pope to draw and paint, but whose Pictures have no drawing, nor colouring, nor composition to recommend them, received a well-known complimentary Epistle from the great Poet; where the growing beauties of some of his young friends are compared with the productions of this Painter.

> Oh! lasting as thy colours may they shine,
> Free as thy stroke, yet faultless as thy line,
> New graces yearly, like thy works display,
> Soft without weakness, without glaring, gay, &c.

It was Jervas who, having copied a Picture by Titian, was so delighted with the superiority, as he thought, of his copy to the original, that he could not resist exclaiming with some degree of pity for the *gone by* Venetian: "Poor little Tit! how he would stare!"

[†] This meritorious designer and Engraver was of an ancient Bohemian family, and was brought up to the profession of the Law; but the capture and plunder of his native city in 1619, during a Civil war, and the consequent poverty and dispersion of his connections, reduced him to take refuge at Frankfort, where, following his predilection for the Art, he became a pupil of Matthew Merian. (Art. 50.) The Earl of Arundel, on his embassy to Ferdinand II, met with Hollar at Cologne, became his patron, attached him to his suite, brought him afterwards to England, and introduced him, it is said, to the notice of Charles I., who had already testified his zeal for graphic improvement in this Country by appointing *Vander Voerst*, a respectable Flemish artist, to the place of King's Engraver, and by giving employment in England to the famous *Lucas Vorstermann* (Art. 40.) from the year 1623 to 1631. It does not appear, however, that Hollar's style was appreciated according to its merits by his contemporaries. But whatever impression he might have made on the Public or his employers was soon effaced in this Country by the miseries of Civil war. His attachment to the Royal cause procured him the honour, in 1645, of being made a prisoner at Basinghouse, in Hampshire, whence on his liberation he repaired to Antwerp, and there continued to engrave from the collection of Earl Arundel, who had succeeded in removing to that city. The death of his patron, however, in 1646, drove Hollar into great indigence, and into the employment of booksellers and printsellers, from whom his utmost industry could obtain but very scanty remuneration. He ventured in 1652 to revisit England, and was employed, but earned barely a subsistence. The return of his friends at the Restoration somewhat bettered his circumstances; but the Fire of London and the Great Plague were necessary obstacles to every pursuit of Art, even if the Court of Charles II. had been less dissolute and less neglectful of modest and deserving men. He was, however, commissioned by the Government in 1568, and the following year, to make drawings of the forts and town of Tangiers, which he afterwards engraved. On his return from this expedition in the ship Mary Rose, Captain Kempthorne, the vessel was engaged by seven Algerine corsairs, off Cadiz; but continued her voyage with the loss of eleven men killed and seventeen wounded. Hollar escaped unhurt, and afterwards commemorated the gallant action in an Engraving. For his two years' service in this undertaking he received only one hundred pounds, which was paid after long delay and many humble solicitations. No life of an artist has, perhaps, been more eventful than that of this industrious Engraver. On his death-bed, at the age of seventy, he is said to have requested the bailiffs, who came to seize his only piece of furniture, namely, the bed on which he lay, to spare him the use of it for a few hours, and then to remove him to the prison of the grave. His Works amount to nearly two thousand four hundred Prints, in every department of the Art, portrait, history, costumes, antiquities, entomology, landscapes, and views, in which latter he particularly excelled. The characteristic of his point is freedom and playfulness, united to great firmness and finish.

Among the pupils of Hollar (none worthy to succeed him) were *Thomas Dudley*, *William Howard*, and *Robert Gaywood*; (they flourished A. D. 1645 or 1650.) Gaywood was wholly a portrait-engraver, and did not confine himself to the style of his master, but studied also, and with some success, Voerst, Vorstermann, and the Vandyke School. *Edward Marmion* is mentioned as a follower of Gaywood. Other imitators of Hollar were *Thomas Cross*, who flourished about A. D. 1658; *Thomas Neale*, *Daniel King*, and *Balthazar Moncornet*, about A. D. 1650; and *John Dunstall* about A. D. 1660. Nearly all these names will be found in Lord Orford's *Anecdotes*.

[*] This artist was pupil of Robert Peake, a Painter and Printseller; afterwards knighted by Charles I. Peake, during the Civil war, obtained the rank of Lieutenant-colonel in the Royal army, and persuaded *Faithorne* to enter the service. Faithorne and his Colonel were made prisoners at Basinghouse; and Faithorne obtained his liberty on condition of leaving the Kingdom. He retired to Paris, where, under the instructions of the celebrated Robert Nanteuil, (Art. 41.) he greatly improved himself. Obtaining permission, about A. D. 1650, to return to England, he established himself near Temple Bar as a Printseller, and afterwards resided in Printing house Yard, Blackfriars, where he continued to engrave and paint portraits in crayons, an Art which he had learnt during his exile in France. His circumstances were straitened, and his death, it is said, was hastened by the dissipation of his son, William Faithorne the younger, who practised Engraving in mezzotinto, but did not outlive his thirtieth year. The Works of the elder Faithorne are numerous, chiefly portraits, many of them admirably executed, clear, brilliant, and full of colour.

John Filian, who flourished about A. D. 1676, was a pupil of the elder Faithorne. He died young; but executed a few portraits.

[†] *David Loggan*, says the noble writer of the *Anecdotes*, is reported to have been taught Engraving by Simon de Passe in Denmark. Passing through Holland, he studied under Hondius, and came to England before the Restoration, bringing over with him *Abraham Blooteling* and *Gerard Valck*, who worked for him in mezzotinto. He distinguished himself by Plates of the public buildings at Oxford; and afterwards at Cambridge. He lived latterly in Leicester-fields. His best and most numerous Works are portraits

Artists' Names.	Where born and when.	Died at	A. D.
Michael Vander Gucht	Antwerp 1660		1725
*George Vertue**	London 1684		1756
Simon Francis Ravenet†	Paris 1706	England	1774
J. B Chatelain‡	England, about 1710		
Francis Vivares	Montpelier 1712	London	1782
*John Browne**	Oxford 1719		
Sir Robert Strange†	Orkneys 1721	London	1792
Giov. Batista Cipriani‡	Florence, about 1728	London	1785
Wm. Wynne Ryland	London 1732		1783
William Woollet§	Maidstone 1735		1785

engraved in a neat but formal style. According to Lord Orford and Vertue, *Vander Gucht* was a disciple of Loggan.

Edward le Davis, a native of Wales, who flourished in 1670, and *Robert White*, a portrait-engraver, born in London in 1645, were pupils of Loggan. White, in 1764, engraved the first *Oxford Almanac*. His son and pupil, George White, etched some portraits in the style of his father; but his best are in mezzotinto.

* The instructor of *Vertue* was *Michael Vander Gucht*, who studied for some time under one of the Boutats, and afterwards settled in England, but in what year is not ascertained. Vander Gucht engraved portraits, book-plates, and anatomical figures, and was succeeded by his sons *Gerard* and *Thomas*, in the same line. Vertue passed seven years under Vander Gucht, and in 1709 set up for himself, and became an excellent draughtsman by studying for several years in the Academy of Painting instituted in 1711, with Sir Godfrey Kneller at its head. His taste led him to antiquarian researches, and to indefatigable inquiry after every object connected with his Art. The *Anecdotes of Painting*, compiled by Lord Orford from the papers of Vertue, fully attest the diligence and fidelity of the latter as a biographer. His engraved Works are distinguished for truth, care, and accuracy, but want force. They are extremely numerous, consisting of portraits, historic Prints, and antiquities of every description. He engraved the *Oxford Almanac* for many years. He was employed by the Knaptons to engrave the Kings of England for Rapin's *History*, and afterwards upon several of the "Illustrious heads," most of which, however, are by Houbraken, (Art. 40.) and much superior to those of Vertue.

† *Ravenet* settled in London about A. D. 1750, and became a powerful acquisition to the English School. He was one of Hogarth's ablest coadjutors. He engraved several portraits after Reynolds and others, and a variety of historical subjects after Titian, P. Veronese, Guido, Guercino, A. Caracci, N. Poussin, L. Giordano, Rembrandt, Carlo Cignani, Le Sueur, &c. His Prints are remarkable for colour, brilliancy, and precision. His son and pupil, *Simon Ravenet*, visited Paris, continued his studies under F. Boucher, and finally settled at Parma, where he conceived and executed, between the years 1779 and 1785, the magnificent project of Engraving the whole of Coreggio's Works in that city.

Among the pupils of S. F. Ravenet in this Country were *William Wynne Ryland* and *John Hall.* Ryland also studied for five years at Paris successively under F. Boucher and P. le Bas. (Art. 56.) On his return to England he was appointed Engraver to the King, and engraved portraits of George III. and Lord Bute after Ramsay; and of Queen Charlotte after Coates. He engraved also some historical subjects after P. da Cortona, Vandyke, Boucher, &c.; but latterly applied himself to chalk Engraving, (after the designs of Angelica Kauffman,) which he greatly improved, and of which, jointly with Bartolozzi, he was the introducer into this Country. Ryland suffered for forgery, August 29, 1783. *John Hall*, his fellow-pupil under Ravenet, was likewise a highly meritorious artist. His Plates are fine specimens of boldness and clearness. His principal portraits are after C. Maratti, Reynolds, and Gainsborough; and his best historical subjects after Dance, West, &c. His "William Penn treating with the Indians," and "Cromwell dissolving the Long Parliament," (both after West,) are well known. Hall, on the death of Woollet, succeeded to the appointment of Engraver to the King. His father, *Charles Hall*, (born about A. D. 1720,) was a respectable Engraver of portraits, and was also much employed in prints of coins, medals, and other antiquities.

Henry Bryer, a pupil of Ryland, and his partner as a Printseller, engraved a few Plates chiefly from designs of Angelica Kauffman.

‡ This artist, a Briton born, was endowed with abilities of the first order: his designs are full of genius, and his Works show uncommon facility. But he was idle and dissolute, and seldom exerted himself until compelled by necessity. It is to be regretted that his peculiar and surprising talent for designing and engraving landscape, either from nature or from his own fancy, was not more regularly employed. He engraved chiefly after Gaspar Poussin and others for the collection of fine landscapes published by Boydell in 1744.

We may here notice a few other Engravers in this class employed by that spirited publisher. *Thomas Chambers*, born in London about A. D. 1724, whose style though firm is not pleasing; *John Wood*, whose landscapes after S. Rosa, G. Poussin, Claude, Rembrandt, Wilson, &c., have considerable merit; *Carlo Faucci*, a Florentine, and pupil of Carlo Gregori; he engraved after Carlo Dolce, P. da Cortona, Rubens, Guido, &c.; *Alexander Bannerman*, born at Cambridge about 1730; *John Hall*, a distinguished scholar of S. F. Ravenet above mentioned; and *Giovanni Vitalbi*, a pupil of Wagner, (Art. 50.) and who worked for Boydell in 1765. Wagner himself had visited England about thirty years before, when among other Plates he engraved portraits of the three Princesses, daughters of George II., and returned to Venice.

A celebrated pupil of Chatelain was *Francis Vivares*, who improved upon the style of his preceptor, and became one of the best landscape Engravers of his time. His happiest efforts are after Claude Lorraine; and when it is considered that in some instances he had actually no opportunity of seeing the original Paintings, it is extraordinary with what truth and ability he has portrayed the airy softness and freshness of that Painter. Vivares engraved likewise many fine Plates after G. Poussin, Gainsborough, Vanderneer, Smith of Derby, the Smiths of Chichester, &c. *Daniel de Lerpiniere*, a supposed pupil of Vivares, engraved many fine landscapes and views of sea-fights, &c. in the same style, which have great merit. The name of another English scholar of Vivares, *P. Paul Benasech*, will be found in the above list, who, according to Basan, worked some time at Paris, but returned to England. He engraved landscapes and other subjects after A. Ostade, Vernet, Dietricy, &c.

* This was another masterly Etcher and Engraver of landscape. His Works after Gaspar Poussin, Teniers, Hobbima, Rubens, Salvator Rosa, Claude, Both, &c. are excellent. *Browne* etched some of the Plates which were finished by Woollet.

† *Strange* may be regarded as the father of his branch of the Art in England. It is remarked of him that he seems never to have known mediocrity; that his very beginnings are perfect; and that throughout his Works no steps can be traced of gradual progress as in the labours of other artists. His early proficiency under Cooper, a drawing-master in Edinburgh, is as highly honourable to his instructor as it afterwards was profitable to himself. The Civil war, however, on the landing of the young Pretender in Scotland, interrupted all artistic studies: and Strange visited Paris, after passing some time in London. On his way to the French metropolis he frequented for a while the Academy at Rouen, and obtained an honorary prize for design against numerous competitors. At Paris he became a pupil of the celebrated P. le Bas, and acquired under that master the management of the dry point. His own admirable productions, consisting of about fifty Plates, show with what success he has improved upon the suggestions and practice of his instructor in the use of that instrument. In 1751 he returned to London, and ten years after repaired to Italy, whither his reputation had already preceded him. In this tour he was greeted everywhere with honours, and made successively Member of the Academies at Rome, Florence, Bologna, Parma, and Paris. Strange held the appointment of Engraver to Geo. III. The honour of Knighthood, which was conferred upon him in 1787, he did not long survive. The peculiar excellence of Strange is the delicacy of effect with which he expresses the softness, roundness, elasticity, and transparency of flesh. No artist, with the exception of Bartolozzi, has been worthy of comparison with him in this very rare graphic quality. His constant practice, it is thought, of making drawings (chiefly in red chalk) from the best foreign masters acquired him this valuable peculiarity.

Pierre Maleuvre, a neat Engraver of the French School, born at Paris in 1740, was a pupil of Sir Robert Strange; and *F. Legat*, who resided in London about A. D. 1780, in the employment of Boydell, was a follower, certainly *non passibus æquis*, but yet respectably.

‡ This artist, says Lanzi, formed his style by studying the works of A. D. Gabbiani, a Florentine Painter. He went to Rome in 1750, passed two or three years there, and then came to settle in England, where, jointly with Bartolozzi, (Art. 50.) his designs became distinguished throughout Europe. He was one of the Members of the Royal Academy at its foundation in 1769 He painted few large Works; but his drawings, which are admirable, are numerous. He engraved a few portraits, and some Plates after Gabbiani, B. Celini, and his own designs.

§ The peaceful life of this great artist exhibits a strong contrast to the wild and adventurous career of many of his graphic brethren;

Artists' Names.	Where born and when.		Died at	A. D.
John Hall	Near Colchester	1739	London	1797
William Byrne[*]	London	1743		1805
Peter Paul Benasech	London about	1744		
John Keyse Sherwin[†]	In England	1746		
Anthony Cardon the younger[‡]	Brussels	1773	London	1816
Simon Ravenet	London about	1755		

England.
Second class.
(Art. 49.)

(59.) Our second list, selected from the more numerous class, must be still more abridged; and will be found to contain many names equally illustrious with those in the first. In some cases we find no small difficulty, as was before observed, in determining whether the etching needle or the graver predominates in Works of this kind. The connoisseur reader will also observe that many Engravers require in strict justice a place in both classes, but our limits preclude the repetition.

Artists' Names.	Where born and when.		Died at	A. D.
Peter Oliver[§]	London	1601		1660
John Evelyn[‖]	Wotton, Surrey	1620		1706
Abraham Hondius	Rotterdam	1638	London	1695
John Griffier[*]	Amsterdam	1645	London	1718
William Lodge	Leeds	1649		1689
Jonathan Richardson		1665		
Sir James Thornhill	Weymouth	1678		1734
William Hogarth[†]	London	1697	London	1764
George Knapton[‡]		1698	Kensington	1788

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such as Hollar, Faithorne, and Ryland. *Woollet's* life is best known by his Works. He was taught by an obscure artist named Tinney, and had not the advantage of any other master. He excelled in every department; in portrait, in history, and in landscape, but particularly the latter. His well-known historical Print, "The Death of Wolfe" after West, gave a greater name to the English School on the Continent than it had ever before obtained. But his landscapes after Wilson are standard models of excellence. No artist has been happier in the judicious arrangement of lines (Art. 14—22.) for distinguishing the varied surfaces of objects, though it must be owned that in representing the softness of flesh he was less successful. Engraving, however, according to modern practice, admits of the joint efforts of several artists on the same Plate, so that each may direct his own talents to those parts for which they are best suited; and we now hardly ever meet with an Engraving the entire work of one hand. Woollet held the appointment of Engraver to George III.

A very able contemporary of this artist was *William Ellis*, who engraved some Plates in conjunction with Woollet, and from whom we have also several fine Prints of landscape from designs of Paul Sandby and Thomas Hearne.

[*] *Byrne* was successively a pupil at Paris of Aliamet and of J. G. Wille. (Art. 39 and 56.) He was an eminent Engraver of landscape, and executed many considerable Works after Domenichino, Claude, Zuccherelli, Claude, Both, Dietricy, Wilson, Hearne, Farrington, Smith, &c. Bartolozzi occasionally assisted him in the figures of his pieces.

[†] *Sherwin* was appointed Engraver to the King. He flourished from 1775 to 1795, and engraved many fine portraits after Gainsborough, Dance, Reynolds, &c. as well as historical subjects after N. Poussin, Reynolds, Stodhart, &c.

[‡] This Engraver took refuge in England A. D. 1790, in consequence of the insurrection in Belgium. He worked for Colnaghi, and was employed in various contemporary publications. His best Plates are after Stodhart, and a Salvator Mundi after Carlo Dolce. His death was premature and hastened by intense application. His father, the elder Anthony Cardon, a Flemish artist, engraved at Naples for Mr. Hamilton.

[§] His father and instructor, Isaac Oliver, was a celebrated Painter of miniatures. (PAINTING, p. 403.) *Peter Oliver*, according to Vertue, etched some small Plates of historical subjects. *John*, a supposed nephew of Peter, both etched and engraved in mezzotinto.

[‖] To this gentleman the Art of Engraving in England is indebted for one of the earliest English publications on the subject entitled *Sculptura*. His Work is rather a pedantic performance, but contains much learned information, and has probably tended in this Country to introduce graphic amateurship among persons of rank and of literary leisure. *Evelyn* etched five Plates of his journey from Rome to Naples about A. D. 1649. Contemporary with Evelyn was another gentleman of considerable graphic talent, *Francis Place*, who was bred to the Law, but took advantage of the Great Plague in London to quit the profession, and exchange the quill for the pencil. He was a man of genius, but without application equal to his abilities. He painted, etched, and engraved in mezzotinto. According to Lord Orford, Place was "offered £500 a year by Charles II. to draw the Royal Navy, but declined accepting it as he could not endure confinement and dependence." His etchings after Barlow are very fine. He likewise engraved portraits after Kneller, Vandyke, Greenhill, &c., which are scarce, as he wrought for his own amusement.

An intimate friend of Place was *William Lodge*, whose father, a merchant at Leeds, was one of the first Aldermen of that town in 1626. Lodge having finished his academical education at Cambridge, and made a commencement at Lincoln's-Inn, attended Lord Bellasis, afterwards Lord Falconberg, on his embassy to Venice, where, meeting with the *Viaggio Pittoresco* of Giacomo Barri, he was so delighted with the Work that he translated it into English, and added, of his own Engraving, heads of the most eminent Painters and a map of Italy, published in 8vo. 1679. He also etched several of his views in Italy, and other Works. Place and his friend Lodge were Members of a Club of virtuosi at York. (See Walpole, *Catalogue of Engravers*, p. 100.)

[*] *Hondius* and *Griffier* were Painters, the former of animals, (of which he has left some fine etchings,) the latter of landscapes and views. Some of *Griffier's* etchings of views on the Rhine and on the Thames are very pleasing.

Other Painters will be found in the above list. *Oliver*, already mentioned, was a *peintre graveur;* also *Jonathan Richardson*, a pupil of John Riley, (PAINTING, p. 494.) and a valuable writer on Art; likewise *Sir James Thornhill*, who executed a few etchings in a bold slight manner; and his renowned son-in-law, *William Hogarth*. (*Ibid.* p. 495.) *F. Zuccherelli* was one of the original Members of our Royal Academy, who, in early life, amused himself with the etching point. The *Smiths* of Chichester, whose landscapes, particularly those of *George*, have employed the ablest Engravers, have left several small sets of etchings after their own designs. *George Stubbs*, the (in his day) inimitable painter of horses, etched the Plates for his "Anatomy of the Horse." *George Barret*, an excellent Painter of Irish and English landscape scenery, has left a few spirited and picturesque etchings *Joseph Goupy*, an eminent Painter in water-colours, etched after Solimene, Rubens, P. da Cortona, N. Poussin, and his own designs. *Sawrey Gilpin*, R. A., etched animals after his own spirited and masterly designs; as likewise some heads for his brother's book, *The Lives of the Reformers*. *Alexander Runciman*, who painted, among other Works, "The Ascension," for the Episcopal Church at Edinburgh, where he presided over the Scottish Academy of Arts, engraved and etched a few Plates from his own designs. *J. H. Mortimer* (see PAINTING, p. 496.) etched in a bold, free style several studies after S. Rosa, Lairesse, &c. *Maria Angelica Kauffman*, R. A., has left several tasteful and spirited etchings; some after Coreggio, but chiefly from her own designs; and, lastly, *L. Schiavonetti*, the disciple and coadjutor of Bartolozzi in England, claims distinguished notice, whose Engravings, after Michel Angelo, Loutherbourg, Stodhart, &c. are well known.

[†] We have already remarked upon *Hogarth* as a Painter. (PAINTING, p. 498.) His style of Engraving is not distinguished by any remarkable dexterity in laying his lines or by delicacy of touch, but by strong characteristic delineation. The unexampled demand for his Works required the assistance of several other hands. Among his foreign coadjutors were *Scotin*, *Baron*, and *S. Ravenet*, (Art. 58.) who worked for him in the "Marriage à la Mode;" *C. Grignon*, who completed his "Garrick" in Richard III., and who, with *Le Cave* and *Aveline*, assisted him in the four Plates of "The Election." But he employed also some able native artists. *Woollet*, in 1759, assisted in some designs from *Tristram Shandy;* and *Luke Sullivan*, a native of Ireland, who had been a pupil of Thomas Major, and who was of a kindred temperament, well suited to catch the humorous conceptions of Hogarth, gave him his best aid, when not engaged (for he was idle and dissipated) in following his own inventions.

Thomas Major, the master of Sullivan, had studied some years at Paris. He engraved in a neat firm style after Berghem, Wowermans, Murillo, G. Poussin, Rubens, Claude, Teniers, &c. Also twenty-four Prints of the "Ruins of Pæstum," published in 1768.

[‡] A scholar of Jonathan Richardson and Painter of portraits in crayons. In conjunction with *Arthur Pond*, a Painter also of portraits in oil and crayons, *Knapton* engraved and published a set of Prints from drawings of celebrated Painters, chiefly landscapes after Guercino, a very creditable performance. Knapton, likewise, among other Works, was engaged in publishing the "Heads of Illustrious Persons," engraved by Houbraken, &c. (Art. 40.) Pond etched

Artists' Names.	Where born and when.		Died at	A. D.
Francis Zuccherelli	Tuscany	1702	Florence	1788
Brothers — *William Smith*	Chichester	1707		1764
George Smith	Chichester	1714		1766
John Smith	Chichester	1717		1764
Edward Rooker[*]	London about	1812		
John Boydell[†]	Dorrington	1719	London	1804
George Stubbs	Liverpool	1724		1806
William Elliot[‡]	Hampton Court	1727		1766
George Barret	Dublin	1728	London	1784
Joseph Goupy	Anvers	1729		1763
Sawrey Gilpin	Carlisle	1733		1807
Alexander Runciman, settled in Edinburgh		1773		1780
John Hamilton Mortimer[§]	Eastbourne, Sussex	1739	London	1779
James Basire[‖]	London	1740		
Angelica Kauffman,[¶] settled in England		1765	Rome	1807
Hamlet Winstanley[*]				1760
Luigi Schiavonetti	Bassano	1765	London	1810

OPUS MALLEI, *or Method of Engraving by the Punch and Mallet.*

(60.) This old method of Engraving, which is now nearly exploded, and which was in some measure calculated to imitate chalk drawings, is a tedious operation, and must have poorly repaid the few artists who have attempted it for their time and trouble,[†] since no more impressions can be obtained than from a Plate slightly etched.

Method styled "Opus Mallei," why disused.

James or *John Lutma*, a Dutch goldsmith, born at Amsterdam about A. D. 1629, is usually mentioned as the best performer in this way. M. Bartsch, however, enumerates four others, beginning with *Giulio Campagnola*, who flourished about 1500. (Art. 35.) A print of "John the Baptist holding a Cup," by this artist, is certainly a curious proof of the antiquity of dotted Engraving. The background is expressed by dots to all appearance executed with the dry point, and the outline of the figure is put in with a deeply engraved stroke finished within with dots.[‡]

Lutma.

Giulio Campagnola.

Of Scraping in MEZZOTINTO.

(61.) This ingenious invention was for some time attributed to Prince Rupert, on the authority of Lord Orford and of Vertue;[§] but Baron Heineken, with more probability, traces it to *Ludwig von Siegen*, who was a Lieutenant-colonel in the service of the Landgrave of Hesse, and by whom a portrait is extant of Amelia Elizabetha, Princess of Hesse, dated 1643, seventeen years before the Restoration in England, when the discovery by Prince Rupert is said to have been made. Heineken maintains that Prince Rupert, when in Holland, learnt the secret from Von Siegen, and brought it into this Country, when he came over the second time to England in the suite of Charles II.[‖]

Invention of mezzotinto scraping by Von Siegen.

Some writers have ascribed to Rembrandt the honour of this discovery; but M. Bartsch, referring to six or seven of the Plates by that artist adduced in proof of the assertion, observes, that although the impressions

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several caricature Prints, and some Plates in imitation of Rembrandt, in a very tasteful and spirited manner.

[*] An admirable Engraver of architectural views. Among his other Works is a Plate with sections of St. Paul's Cathedral, and views after Wilson and Paul Sandby. His son, *Michael Rooker*, acquired considerable celebrity in the same way, and engraved head-pieces to the *Oxford Almanacs* for many years. Michael was one of the first Associates of the Royal Academy.

[†] Few men by individual energy and ability have contributed more in any Country to the promotion of the Arts than this estimable Englishman towards their advancement in his own. He was brought up by his father, who was a land-surveyor, to the same business, but was so attracted by a book of Prints containing views in England, particularly some by *Toms*, a respectable Engraver of architectural subjects, that he came to London at the age of twenty-one to bind himself a pupil to that artist, and for six years applied himself assiduously to the Art. After leaving Toms, *Boydell* engraved and published several views of his own near London and throughout England and Wales, a popular Work in one volume, for five guineas. From this beginning he rose to considerable wealth and reputation. He often spoke in after-times of this Work as the "first book that ever made a Lord Mayor of London." His judicious and liberal management of an extensive commerce in Prints throughout Europe gave him means and opportunity of employing the ablest artists of his time, and of exporting to advantage what had formerly been an article of constant importation from the Continent. Boydell's property, however, was so greatly injured by the French Revolution, that his celebrated Shakspeare Gallery, which he had intended to bequeath to the Public, was disposed of by lottery. He was elected in 1770 Alderman of his Ward, and in 1791 served the office of Lord Mayor.

Under our former list (see Note on *Chatelain*, Art. 58.) we mentioned some names of Engravers employed by Boydell. We may here add *T. Taylor*, who worked after S. Rosa and Van Harpe, and from vignettes designed by J. Gwyn; *James Peak* after Claude, Wilson, J. Smith, Borgognone, &c.; *Anthony Walker* and his brother *William*: the former (a fellow-pupil with Woollet under John Tinney) engraved after P. da Cortona, Holbein, Rembrandt, Chatelain, and others; the latter after Vandyke, Le Moine, Rubens, Trevisani, Van Harpe, &c. William is said to be the inventor of an expedient for rebiting etched Plates, by the application of fresh varnish with a dabber, (Note (BB.) at the end of ENGRAVING,) a most useful discovery, of which Woollet occasionally availed himself; and whenever it succeeded to his mind would usually exclaim, "Thank you, William Walker."

Among foreigners who settled in England under Boydell's encouraging support were *Pietro Antonio Martini*, born at Parma 1739, who had etched for Le Bas at Paris; *Matthew Liart* and *Jean Baptiste Michel*, both Parisians; and *Victor Maria Picot*, born at Abbeville in 1744, and employed by Boydell about A. D. 1770.

[‡] A fine landscape Engraver with a free and tasteful point, after Cuyp, Rosa da Tivoli, and Polemberg, but chiefly after the Smiths of Chichester, for whom see the above list.

[§] A very clever pupil of *Mortimer* was *Robert Blyth*, who has etched some of that master's drawings with a spirit such as they well merit.

[‖] *Basire* engraved after Reynolds, Wilson, West, &c., and is remarkable for producing the largest Print ever executed on one Plate (about 27 inches by 47) from the Picture at Windsor, representing "The Field of the Cloth of Gold." *John Green*, a pupil of Basire, engraved several landscapes and views and a few portraits. Green likewise engraved the *Oxford Almanacs* for many years.

[¶] We might mention other ladies who have contributed to adorn the English School of Engraving, but ought not to omit our Countrywoman, Miss *Hartley*, a charming etcher, who flourished about 1764.

[*] A pupil of Sir G. Kneller, on leaving whom he visited Italy and afterwards returning to England devoted himself entirely to Engraving. He etched a set of Prints from the Paintings of Sir W. Thornhill in the cupola of St. Paul's; also about twenty Plates from the collection of the Earl of Derby, after Titian, Tintoretto, P. Veronese, Bassano, Guido, Castiglione, Spagnoletto, C. Maratti, Rubens, Vandyke, Rembrandt, &c. His father, *Henry Winstanley*, was the unfortunate projector and builder of the Eddystone Lighthouse, and perished in the ruins during the storm in the year 1703. Henry Winstanley designed and etched several views, dedicated to James II., with a complimentary address to Sir Christopher Wren.

[†] See Note (CC.) at the end of ENGRAVING.

[‡] In the year 1560, an artist at Bologna, *Geronymo Fagiuoli*, produced some punched Plates after the drawings of Coreggio, C. del Salviati, and Francesco Mazzuola. He superadded, however, the use of the graver.

[§] See Walpole's *Catalogue of Engravers*, in the fifth volume of the *Anecdotes*, p. 137. Evelyn, at the head of chap. vi. of his *Sculptura*, calls mezzotinto *the new way of Engraving invented and communicated by his Highness Prince Rupert, Count Palatine of the Rhine, &c.*

[‖] See Heineken's *Idée générale d'une Collection complette d'Estampes.* A mezzotinto Print is extant by Lieutenant-colonel van Siegen, representing the "Holy Family," after Caracci, and inscribed with the following dedication: *Eminentissimo Principi Domino D. Julio Mazarino S. R. E. Cardinali, &c. Novi hujus Sculpturæ modi* primus inventor *Ludovicus a Siegen humillissime offert, dicat, et consecrat. Anno* 1657.

from them bear some resemblance to Prints in mezzotinto, they have evidently never been prepared by the instrument called the cradle, (see Note (DD.) at the end of ENGRAVING,) on the use of which the velvet-like appearance peculiar to this method depends.*

Followers of Von Siegen in Germany

Among the German followers of Von Siegen, Bartsch enumerates *Johann Friederich von Eltz* and his pupil *Johann Jacob Kremer; Martin Dichtl*, a Painter and Engraver of Nuremburg; *Caspar von Furstenburg*, who flourished in 1656; *Johann Franz Leonart*, at Nuremburg in 1687; *Benjamin Blocke*, Painter, born at Lubeck, 1631; also in the following century, *Johann Jacobb*, born at Vienna in 1733, who died in 1797; and *Joh. Pichler*, born in 1766, at Botzen in the Tyrol, who died in 1806. He concludes his list with the name of a Professor of mezzotinto in the Academy at Vienna, *Vinzenz Kininger*.

Holland, and Flanders.

Among Dutch and Flemish artists are:

Artists' Names.	Where born and when.	Died at	A. D.
Johann Thomas	Ypern 1610		
Wallerant Vaillant†	Lisle 1623	Amsterdam	1677
Johann van Somer	Flourished about 1625	An indifferent artist.	
Paul van Somer,	settled in England, and died in London 1694.		
Abraham Blooteling‡	Amsterdam 1634		
Gerard Valck	Amsterdam 1606		
Johann van Gole	Amsterdam, about 1660		
Johann Verkolie§	Amsterdam 1650		1693
Nicholas Verkolie	Delft 1673	Amsterdam	1746

Very few Italian or French artists in mezzotinto.

The Italian and French artists in mezzotinto are so few, and have made so little progress, that M. Bartsch has omitted them altogether. Among Italians, however, we may mention *Giuseppe Marchi*, who was brought from Italy by Sir Joshua Reynolds, and employed by him in painting his draperies. In France, the earliest attempts in mezzotinto were by *Jean Sarrabat*, born at Andely A. D. 1680. They are coarsely executed. We may add *Charles Maucourt*, born at Paris about A. D. 1743, who died in London in 1768; and *Nicolas Bounieu*, a native of Marseilles, A. D. 1744, and a Member of the Academy of Paris in 1775, whose Paintings are not much known in England. He scraped in mezzotinto from his own designs. *Boyer, Marquis d'Aiguilles*, was an amateur performer of some ability in this way as well as in Painting.

English artists in mezzotinto.

(62.) In our English list we include only the following names of remarkable artists:

Artists' Names.	Where born and when.	Died at	A. D.
*John Oliver**	1616.		
William Faithorne the younger.	(See Art. 58. for his father.)		
Henry Lutterel †	Dublin 1650		
Isaac Becket	1653		
Edward Kirkall. (Art. 46.)	about 1695		
James M'Ardell‡	Ireland about 1710		1765
Richard Houston§			1775
Thomas Frye	born about 1724		
J. Finlayson	about 1730		
Valentine Green‖	Warwickshire 1739	In London	1813
John Blackmore	about 1740		
Robert Laurie	about 1740		

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* The seven Plates alluded to are "etched," says M. Bartsch, "in the ordinary way, and the apparent washes for his ground, &c. as well as the soft velvet-like masses for his draperies, &c. seem the result of a peculiar method of printing. Rembrandt himself placed the black colour on his Plates, and previously to impression, only cleared those parts of them which he intended to be in clear light. The degree of depth in the black, which was to appear in the impression, depended upon the greater or less quantity of colour left upon the copper. Hence we may trace the cause why several impressions of the same Print by Rembrandt are so dissimilar, and why scarcely any two of them are alike perfect." *Anleitung, &c.* vol. i. sec. 528.

† A Painter of some reputation, who, it appears, came to England with Prince Rupert, and was instructed by the Prince in the Art of mezzotinto scraping. *Vaillant* was taken to Paris by De Grammont, where he was much employed and enriched by his success in portrait. His brother, *Bernard Vaillant*, a portrait-painter in crayons, has left some mezzotinto Plates in the same style of execution.

‡ *Blooteling* visited England in 1672, or 1673. He was brought over by Loggan, (Art. 58.) together with *Gerard Valck*, his brother-in-law, whose Engraving of the "Duchess of Mazarin," Lord Orford pronounces to be "one of the finest Prints we have." Blooteling was an able and indefatigable artist, and excelled both in etching, Engraving, and mezzotinto.

§ A Painter of small portraits, well coloured and delicately finished. His son *Nicholas Verkolie* followed for some time the same line of Art, but afterwards painted some very able and justly admired historical pieces. In mezzotinto, he improved upon his father's style, and was much distinguished.

M. Bartsch might have named others equally worthy of mention with those in the above lists, both among his Countrymen and in the Flemish and Dutch School. Among Germans, *Christopher Weigel*, who flourished about A. D. 1650; *G. P. Rugendas*, born at Augsburg in 1666, celebrated for skirmishes and lion-hunts, together with his son *Christian; C. Heiss*, a Painter born in Suabia, about A. D. 1670, some of whose Prints are three feet by two, and upwards; *Bernard Vogel*, born at Nuremburg, 1683; *John Jacob Haid*, of Wirtemberg, born 1703, a Painter and pupil of Ridinger; (his sons *Gottfried* and *Elias*, born in 1730 and 1740, at Augsburg, the eldest of whom worked for Boydell, were respectable artists in this way;) *G. B. Goetz*, a Moravian Painter, born A. D. 1708; *J. V. Kaupers*, born in Stiria A. D. 1741, a scholar of James Schmutzer; and lastly, the two *Preistlers*, from Vienna and Nuremburg, whose works in this line are, it is true, inferior to their other productions.

Among Flemish and Dutch scrapers, *John van Hugtenburg*, born at Haerlem A. D. 1645, who died in 1733, was an admirable battle-painter, and has left some fine graphic specimens; *Vander Wilt* and *D. Koedyck* flourished about A. D. 1680; *Cornelius Troost*, styled the Dutch Watteau, was born at Amsterdam A. D. 1697, and died in 1750; *Peter Schenck*, who scraped portraits of British Sovereigns, and one hundred views near Rome, and *N. van Haeften*, (see *Peintre Graveur*, vol. v. p. 445.) flourished about A. D. 1700; *P. van Bleck*, about A. D. 1730; and *F. Vander Cam*, about A. D. 1750.

* Nephew of *Peter*, (Art. 59.) and a much admired Painter on glass.

† "Was bred," says Lord Orford, "at New Inn, but abandoned the Law. He set himself to discover the secret, for so it then was, and laid his grounds by a roller, (*roulette*, see Note (GG.) at the end of ENGRAVING,) which succeeded tolerably, but not to his satisfaction. He then persuaded his friend Lloyd, who kept a printshop near the Strand, to bribe one *Blois* (who laid grounds for *Blooteling*, and was returning to Holland) to disclose the mystery. Lloyd for forty shillings purchased the secret, but refused to make it known to *Lutterel*, on which they quarrelled. Meantime *Isaac Becket*, a calico-printer, found means of inducing Lloyd (who was ignorant how to put his knowledge into practice) to accept of his services; and Lutterel having made the acquaintance of *Paul van Somer*, (Art. 61.) learned from him the whole process. Becket getting into difficulties was assisted by Lutterel, and they became intimate; but Becket, on his marriage afterwards to a woman of fortune, set up for himself, and employed Lutterel, who was the better draughtsman, to assist him. This was the introduction of mezzotinto into the English School.

‡ One of the ablest artists in this kind of Engraving. His Prints are very numerous. He scraped some admirable Plates of historical subjects after Rubens, Vandyke, Rembrandt, Murillo, &c., but chiefly portraits after Hudson, Reynolds, Zoffany, Vandyke, &c. Other natives of Ireland were popular artists in this line. *Thomas Beard*, who flourished about A. D. 1728, and *John Brooks* about 1742. *Charles Spooner*, an Englishman, resided in Dublin and scraped several Plates, dated from 1752 to 1762.

§ Another of the first rank in mezzotinto. His portraits after Reynolds are excellent, and his historical productions, chiefly after Rembrandt, very fine.

‖ Was bred to the Law; but after two years' study gave up the profession, and without the aid of an instructor arrived at a proficiency in mezzotinto which few have attained. The Prints after West of Hanibal and Regulus raised him into general admiration. His Works after West and other masters are numerous; as also portraits after Reynolds, Romney, Zoffany, &c.; and he shares the honour with *M'Ardell* and *Earlom* of giving consequence and variety to the particular style of Engraving to which these ingenious men devoted themselves. *Green's* Works amount to nearly four hundred Plates, the labour of about forty years. In 1774, he was elected one of the six Associate Engravers to the Royal Academy.

Artists' Names.	Where born and when.	Died at A. D.
*Thomas Watson**	London........ 1750	1781
John Raphael Smith†	Derby about 1750	1811

The Fabers.

A few other names will be found below of artists equally eminent, but whose date of birth is unknown.‡ *John Faber* the elder, from Holland, settled in England about A. D. 1695, and scraped many portraits highly interesting to the English collector. His son, *John Faber the younger*, surpassed his father, and was the ablest portrait scraper of his time, except John Smith. But the great modern improver of mezzotinto is our venerable

Earlom.

Countryman, *Richard Earlom*, whose portraits after Rembrandt, Vandyke, Reynolds, and West, are in every good collection, together with historical subjects after numerous ancient and modern masters; and whose Works are well appreciated by M. Bartsch, as exhibiting considerable advancement in the Art by a judicious introduction of lines and dots never before attempted with success. (Note (EE.) at the end of ENGRAVING.)

Method of LE BLON, *by Printing* MEZZOTINTO *in Colours.*

Method of Le Blon.

(63.) The impressions for Plates executed in the methods we have hitherto been considering are calculated more or less for giving effect to the chiaroscuro of a Picture; but as the chief excellence of many Paintings consists in a judicious arrangement of different colours, there was still wanting some discovery by which colour as well as form and shading might be transferred to chalcographic Prints. Mezzotinto, above all other methods, has the peculiar property of imitating the soft gradation of tint produced in shading with a brush; and this advantage must of course be still greater if a diversity of colours be superadded. The method of *Le Blon* (see Note (FF.) at the end of ENGRAVING) seems ingeniously calculated for obtaining this desideratum, and for multiplying copies of any Painting so as to correspond with it in every particular, and to present to the spectator's mind a perfect idea of the original.

Its fitness for gradations of colour.

Lastmann.

M. Bartsch mentions several prior attempts at coloured Engravings; namely, by *Lastmann* of Haerlem, as early as the year 1626; by *Peter Schenck* of Amsterdam in 1680; and by *Taylor*, an English engineer in the service of Frederic the Great: but these attempts were made only from etched lines, and by means of one and the same Plate. Coloured mezzotintos have been also tried by means of one Plate; but these, like the former, have proved failures. Impressions so obtained do not possess the proper combination of tints, especially in the lights, where many traces of white paper may constantly be detected. The Prints, consequently, from such coloured single Plates continually require retouching by the artist; whereas those obtained in Le Blon's manner by means of three and sometimes four successive Plates, are almost wholly and uniformly covered with colour.*

Chalcography. Schenck. Taylor and others.

Their attempts with one plate unsuccessful.

French Method for CHALK *Engraving.*

French imitation of chalk drawings.

(64.) This method, in imitation of drawings in chalk of academic studies and subjects, is an invention shared by three French artists: *G. E. Demarteau*, born at Liege in 1722,† who died at Paris A. D. 1776; Jean Jacques François,‡ born at Nancy in 1717, who died A. D. 1769; and *Louis Bonnet*, a native of Paris, about A. D. 1735. Bonnet executed several Prints in this way chiefly after Boucher.

The means and instruments employed in this style of Art (see Note (GG.) at the end of ENGRAVING) are not adapted to express the delicate details of a Picture, and are employed rather for producing bold broad lines and coarse shadings, than for imitation of drawings finely executed or highly finished. There are, however, few or no methods of Engraving so successful as this in accomplishing the purpose intended. Many Prints of this kind so closely resemble drawings in red chalk that they might almost be mistaken for their originals.

Perhaps the most deservedly celebrated artist in this way is an amateur gentleman of Amsterdam, born there in 1732, *Cornelius Ploos van Amstel*, who has executed a numerous and interesting collection of Plates imi-

P. van Amstel.

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[*] His Prints are numerous and excellent in this way, though he died at the premature age of thirty-one. He employed his scraper on portraits after Reynolds, Lely, Dance, West, &c., as well as on various subjects after Rembrandt, Coreggio, and other masters. *James Watson*, his relation, (a younger brother, according to M. Bartsch,) was no less distinguished. His Prints after Reynolds are in great esteem; as likewise other portraits after Vandyke, Gainsborough, Romney, &c.

[†] Son of Thomas, the celebrated Etcher and Painter of English landscape, called Smith of Derby, to distinguish him from the Smiths of Chichester, his contemporaries. The portraits by *Raphael Smith*, after Reynolds, Northcote, Gainsborough, and Sir Thomas Lawrence, are particularly admired.

‡ Artists' Names.	Flourished A. D.	Subjects and Masters.
John Smith	About 1700	Fine portraits after Kneller, and various subjects after Coreggio, &c.
Robert Williams of Wales,	About 1715	Portraits after Vandyke, Kneller, &c.
George White	About 1720	See Loggan. (Art. 58.)
Edward Fisher	About 1765	Fine portraits, chiefly after Reynolds.
Charles Phillips	About 1765	After Mola, Rembrandt, &c.
John Dixon	About 1770	Fine portraits, chiefly after Reynolds.
William Pether	About 1770	Fine plates after Rembrandt, &c.
Philip Dawe	About 1771	Several subjects after Morland, &c.

[*] *James Christopher le Blon*, born at Frankfort in 1670, is said to have been a scholar of Carlo Maratti. He accompanied Bonaventura van Overbeck to Amsterdam, and was there employed in painting miniature portraits. He visited England and perfected many large Pictures according to his new method, which may be allowed, says Lord Orford, who knew him, to be "very tolerable copies of the best masters." But this ingenious projector was unsuccessful with the British Public. He published, in 1730, a detailed account of his process, and died ten years after in an hospital at Paris.

M. Bartsch mentions *Jean Fabian Gautier* of Marseilles, and his son *Edouard Gautier Dagoty*, born A. D. 1745; together with *Jean l'Admiral* at Leyden, and *Carlo Lasinio* a Venetian, as successors to Le Blon in prosecuting this ingenious discovery. Le Blon, however, the discoverer, has produced the best specimens, but better might certainly be executed. He employed a number of Engravers for completing his Plates who did not always come up to the conceptions which we take for granted Le Blon as a clever colourist entertained. In most of his pieces some fault appears in the drawing, or in the chiaroscuro, or in the harmony of colour, and often in all these three particulars united. If any good Painter, as skilful with the scraper as in the use of his palette, should undertake a similar enterprise, far superior results might be attained.

[†] *Giles Demarteau the younger*, a nephew of the above, born at Liege about A. D. 1750, followed the style of his uncle and preceptor with some success. *D. P. Pariset*, born at Lyons in 1740, another pupil of the elder *Demarteau*, was employed in England in 1767 by Ryland, and engraved the Plates from drawings by the great masters published by Rogers. He also engraved "Portraits of English artists" after designs by Falconet.

[‡] *François* is said to have been the first who engraved at Paris in this style, and to have been rewarded for his ingenuity by a pension of five hundred livres from the French King.

tating crayon drawings by the most distinguished Dutch masters.

English Method by DOTTING.

English improved method by dotting.

(65.) This is an improvement on the preceding method, inasmuch as it imitates with perfect accuracy and clearness the most highly finished chalk drawings. In respect of graphic execution it is far preferable, since the needle and the burin can be much more conveniently and dexterously managed than the roulette. (See Note (HH.) at the end of ENGRAVING.) The dots also are much finer, are more closely ranged together, and if worked judiciously on the metal have a clearer effect than in the French style. The whole work has the appearance of a finely stippled miniature; and attempts have been made, not unsuccessfully, to take coloured impressions from Plates of this kind, which have all the finish and delicacy of miniature-painting.

Bylaert.

The discovery of this method of Engraving, which is traced to the year 1760, originates properly, says M. Bartsch, from *Jacob Bylaert*, a Painter and Engraver at Leyden, who has published in a little Treatise the elements of this Art.

Bartolozzi.

But as *Bartolozzi*, (Art. 50.) who then resided in London, was one of the first to practise it, and to enrich the invention with improvements of his own, exhibited in numerous fine specimens which he shortly after published, he has been regarded as the inventor. Not all the dotted Engravings, however, which bear his name are entirely from his hand. On account of the unexampled demand for his performances, he could not complete his numerous orders without assistance, and without employing several of his scholars, whom he allowed to complete many Plates (previously etched by himself) by the process of dotting. Among them was B. Pastorini, an Italian employed by Bartolozzi in 1770. Also *Schiavonetti* already mentioned. (Art. 59.)

Ryland.

mith.

Menageot.

yder.

trutt.

William Wynne Ryland, whom we have already mentioned, (Art. 58.) was eminent in this way, and published upwards of two hundred Plates, which for delicate finish exceeded all former attempts. Some of them, printed in coloured inks, were, according to M. Bartsch, not inferior to miniature-painting. *Gabriel Smith*, who had learned Chalk Engraving at Paris, practised it in this Country, with the assistance of Ryland, after the improved manner. *Robert Menageot*, born at Paris A. D. 1748, worked for Boydell after Coreggio, Guido, Loutherbourg, &c. *Thomas Ryder* flourished about 1790, and engraved in this style after J. Wright, West, Opie, A. Kauffman, Shelley, &c. Not to omit *Joseph Strutt*, born about A. D. 1745, author of the *Dictionary of Engravers*, who has executed several neat and delicate prints of this kind.

urke and
ther mo-
erns.

Thomas Burke, whom M. Bartsch styles a "firm draughtsman," published between the years 1770 and 1780 several beautiful specimens in this (then novel) style. M. Bartsch names among his own contemporaries in Germany *Henry Sinzenich* of Manheim; *Charles Hermann Pfeiffer* of Vienna; together with *F. John*, a pupil of the latter.

AQUATINTA, *or Imitation of Washed Drawings in Bistre.*

*mitation of
rawing in
vater-
olours.*

(66.) This is another graphic invention for the purpose of imitating another kind of drawings; those, namely, which have been executed with brushes of camel's hair in Indian ink or bistre, by the process technically termed *washing*. There has been much disputing among artistic biographers as to the inventor of this Art. M. Bartsch inclines to the opinion, that it originated in France with a distinguished author and amateur Engraver, the *Abbé de St. Non*, who, careless of any gains to himself by the discovery, communicated it to his friend, *Jean Baptiste le Prince*, a French Painter of some celebrity, with a view of benefiting that artist. Le Prince, during his lifetime, published in 1780 an advertisement, offering for a specified sum to give instructions in the unknown process; and at his death, which happened in the following year, he bequeathed the secret to his niece and heiress, from whom the French King, (see Note (II.) at the end of ENGRAVING,) in order to impart it generally to the Academy and to the Public, purchased it by granting her a pension.

St. Non and others.

Beside St. Non and Le Prince, several artists, both of France and other Countries, have been named as the inventors; but their methods of attaining the same object have been considered so inferior to that of Le Prince, as to be superseded by the latter, as soon as it became publicly divulged.*

Artists in aquatinta.

The most distinguished names in this style of aquatinta are

Artists' Names.	Where born and when.	
Richard Abbé de Non	Paris	1730
Paul Sandby†	Nottingham	1732

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* M. Bartsch, quoting from Rost's *Handbuck*, (band viii. s. 230.) mentions three Plates engraved by *St. Non* after Robert, in washes of black and brown, as early as A. D. 1766, consequently two years earlier than any of Le Prince's productions: also five series, consisting of one hundred and fifty Plates, executed by the same hand, in Le Prince's best manner, entitled *Fragmens choisies dans les Peintures et les Tableaux les plus interressans des Palais et des Eglises d'Italie*, which were published between A. D. 1772 and 1775, nine years before the death of Le Prince. Hence the doubt arises whether Le Prince really was the inventor, and the certainty that if he was he did not conceal the secret from St. Non.

Writers upon Art also bring forward the French artists, *Barabé*, *Delafosse*, *P. F. Charpentier*, together with *P. Floding*, a Swede; *A. Pond* and *C. Knapton*, our Countrymen; *J. A. Schworikard* of Nuremburg, and *Ploos van Amstel* of Holland, as claiming the discovery. These artists, however, either made ingenious combinations of methods previously known, or what they did invent fell very short of Le Prince's method. Pond and Knapton, in 1734 and 1735, published imitations of drawing in bistre; but in these the outlines alone are etched upon the copper, and the washes have been put in by means of two, three, or even four wooden blocks in the style of Prints in chiaroscuro. (Art. 28. and Note (P.) at the end of ENGRAVING.) In the years 1758 and 1759 several Plates were executed for the Work of Ant. Dom. Gabbiano, at Florence, entitled *Racolta di Cento Pensieri*, fol. 1762. These Prints represent lightly washed drawings, put in with one, or at most with only two weak tints. But these tints are produced without any intervening substance, and by pouring the solution of aquafortis on the pure copper. A few dark shadings are introduced with the burin or dry point, and occasionally with small rasps or graining tools. These Prints were executed by J. A. Schweikard, in conjunction with Santi Pacini, Carlo Gregori, Antonio Cioci. Andr. Scacciati, Gio. Bat. Galli, Ignaz Hugford, and Vincenzio Vangelisti, Peter Floding and Ploos van Amstel, in one or other of the two methods last mentioned. Stapart, an amateur, published at Nuremburg, in 1773, a Treatise entitled *The Art of Engraving with a Brush on Copper*. (See Note (II.) at the end of ENGRAVING.)

† *Paul Sandby* is a truly British artist, one of those who first convinced Englishmen that the features of their own native island are quite as capable of pictorial effect as the scenes on any foreign clime whatever. At the age of sixteen he was employed as draughtsman under Mr. David Watson, to complete a survey of the North and West parts of the Highlands of Scotland, at the instance of the late Duke of Cumberland. Here he occasionally obtained leisure from drawing plans to sketch the wild and terrific scenery around him. These *coups d'essai* he afterwards etched in small Plates.

Artists' Names.	Where born and when.		Died at	A. D.
*J. Bapt. le Prince**	Paris	1733	Paris	1781
Johan Gollieb Prestel	Grunebach in Swabia	1739	Frankfort	1808
Maria Catharine Prestel†	Nuremburg	1747		1794
William Kobell‡	Manheim	1766		
Carl Kunz§	Manheim	1770		
Thomas Girtin||	London	1775		1802

Aquarilla, *or Imitation of Drawings washed in different Colours.*

Improved imitations of drawing in water-colours.

(67.) This style of Engraving is a further attempt to imitate the brush of the painter in water-colours. Like the invention of Le Blon, (Art. 63.) it requires as many Plates as there are simple colours to be used. (See Note (KK.) at the end of Engraving.) It is characterised by a decided superiority over the last-mentioned process, in one remarkable particular, namely, in being capable of representing those shadows of a drawing which vanish imperceptibly into lighter and thinner tints, or which gradually disappear in the lights: an effect not producible by any other method of imitating washes in water-colours. The discovery was made in 1762, by *Pierre François Charpentier*, an Engraver at Paris, born at Blois in 1730. It remained for a long time the sole property of French artists, few of whom have been induced to communicate their modes of working. Among the most remarkable are *François Janinet*, born at Paris, in 1752, and his pupil *Charles Melchior Descourtis*, a native likewise of Paris, in 1753. *Charles Benazech*, who was born in London, but resided chiefly at Paris, and whose profession as a Painter qualified him peculiarly for executing Prints of this kind, has produced several highly skilful specimens.

Lithography.

Lithography.

(68.) Having enumerated and remarked upon the various kinds of Prints from wood and from metal, we now come, in conclusion, to the third material which modern Art has called into similar use; and proceed, as was proposed, (Art. 12.) to give some account of impressions from stone.

Senefelder.

Alois Senefelder,* whose name will long be conspicuously memorable in the annals of modern discovery,

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His talents and rising reputation introduced him soon after his Northern expedition to the notice and patronage of Sir Joseph Banks and Sir Watkin Williams Wynne. By Sir Joseph he was invited to accompany him in a tour through North and South Wales, and by Sir Watkin was employed to design the most interesting parts of Welsh landscape. He subsequently engraved these views in aquatinta. Sandby was one of the original Members of the Royal Academy in 1768, and was the same year appointed chief drawing-master to the Royal Military Academy at Woolwich, an office which he held until his death.

* *Le Prince* studied Painting under J. M. Vien and F. Boucher. He obtained some reputation at Paris, and travelled to Russia, where, during a residence of several years, he employed himself to design the various costumes of that vast Empire, and returned to Paris with a numerous collection of drawings, from which he either completed Paintings or executed Prints. His designs were much admired, and gave exercise to the talent of several other Engravers, his Countrymen.

† This lady was the wife of the preceding artist and aided him in some of his best Plates, particularly in landscape. Some disagreement occasioned her to separate from him and come to England in 1786, where she executed some Plates, which in this style have not been surpassed. They are spiritedly etched, and finished in aquatinta with delicate and picturesque effect. Her husband had studied Painting at Venice under Giuseppe Nogari, and Engraving under Wagner. (Art. 50.) He resided chiefly at Nuremburg, where he worked in various styles. His Prints in aquatinta are numerous.

‡ *William Kobell* was a pupil of his father *Ferdinand*, from whom he learnt to engrave and paint in landscape. Both were eminent in the line they adopted; but William was particularly happy in representing the peculiar style of the principal Dutch masters, after whom he executed a variety of Plates. He also engraved in the crayon manner.

§ Painter of cattle and landscape, and distinguished for many clever Engravings in this style, particularly for three large cattle pieces after Henry Roos, Paul Potter, and A. Vandevelde: *chefs-d'œuvre* in this way.

|| Future writers on English Art will have the duty of recording the rise and advancement of water-colour Painting in this Country, to a degree of excellence not hitherto considered attainable, until the talent and perseverance of a numerous School among the contemporaries or fellow-students of *Thomas Girtin*, called it forth. No true lover of the Arts in England but must be familiar with the names and merits of the "Society of Painters in Water Colours." We purposely abstain from remarks on living genius, but must observe of Girtin that he was one of the earliest and most successful improvers of the Art in question. For this purpose he found no necessity for foreign travel, but studied nature, English nature, at home. Like Rembrandt, Cuyp, Ruysdael, Hobbima, Paul Potter, and other great colourists of the Flemish and Dutch Schools, he found abundant exercise for a powerful mind, in scenes which pass unheeded before the vacant eyes of ordinary men. He visited Paris for his health in 1802, and made sketches of certain streets and public buildings of the French Capital, which, at his return to London, he etched and engraved in aquatinta. His death, however, that same year, removed a valuable contributor to this department of Engraving, and deprived water-colour Painting of one of its ablest founders.

Among other English artists, distinguished in aquatinta, we might mention *James Bretherton*, who flourished from 1770 to 1790, and whose son *Charles*, an early victim to consumption, executed several Plates of great merit, and many charming designs. About A. D. 1790 likewise flourished *J. Baily*, whose landscapes and views in this style of Engraving are highly creditable.

* Peter Senefelder, the father of the inventor, was an actor at the Theatre Royal in the city of Munich, and intending to bring up *Alois* to the profession of the Law, placed him at the University of Ingolstadt. The dramatic inclination, however, of young Senefelder displayed itself in private theatricals; and a little Comedy entitled *Die Mädchenkenner*, which he composed in 1789, gained him some applause and profit. This success, and the death of his father, which straitened his circumstances, determined him to quit the University and attach himself to the Theatres. In this precarious pursuit he passed two years. His second publication of a Play being too late for the Easter book fair at Leipzig, produced but barely sufficient to pay for the printing, during which he had passed much time at the printing-office in anxious endeavours to accelerate the Work. His active mind was here first directed to the business of the pressman. "I thought it so easy," he observes in his Work on Lithography, "that I wished for nothing more than to possess a small printing-press, and thus to be the composer, printer, and publisher of my own productions." After a variety of experiments, during which he was obliged to try methods which he found less expensive and more manageable, he employed, among other materials, blocks or slabs of Kelheim stone, and on these endeavoured to etch his composition, but with very imperfect success. "I had just succeeded," says he, "in my little laboratory in polishing a stone plate, which I had intended to cover with etching ground, in order to continue my exercises in writing backwards, when my mother entered the room, and desired me to write her bill for the washer-woman, who was waiting for the linen. I happened not to have even the smallest slip of paper at hand, as my little stock of paper had been entirely exhausted by taking proof impressions from the stones; nor was there even a drop of ink in the inkstand. As the matter would not admit of delay, and we had nobody in the house to send for a supply of the deficient materials, I resolved to write the list with my ink prepared with wax, soap, and lamp-black, on the stone which I had just polished, and from which I could copy it at leisure. Some time after this I was going to wipe this writing from the stone, when the idea all at once struck me to try what would be the effect of such a writing with my prepared ink, if I were to bite in the stone with aquafortis; and whether, perhaps, it might not be possible to apply printing ink to it in the same way as to Wood Engravings, and to take impressions from it."

The result of this incident was the discovery of the Art of Printing from stone. Unable, however, from the want of pecuniary means, to prosecute his invention, Senefelder took the resolution of enlisting himself in the service of the Elector (afterwards King) of was the ingenious originator of this new opening for the exercise of graphic talent. The comparative cheapness of the materials used, the rapidity of Lithographic execution, the facility with which the hand of any good draughtsman, accustomed to the proper use of a pen or crayon, may transmit his efforts to the press, and obtain a faithful and identical delineation, together with the almost inexhaustible number of impressions, render this form of Engraving worthy of even greater and more general cultivation than has hitherto been bestowed upon it. (See Note (LL.) at the end of ENGRAVING.) It would be absurd to say that Engravings of the Lithographic School are ever likely to supersede those upon wood or metal. Each of these three departments in the Art has its peculiar charms, perfections, and advantages. As well might it be maintained that the several walks of Poetry interfere with or supplant each other; that the sonnet, for example, or the elegy, or the ode, or the wood-notes wild of Shakspeare, or the fascinations of Byron, are calculated, with readers of taste and judgment, to displace the grand and regularly sustained epic of Milton, and his great models in ancient song. The Lithographer of talent, in like manner, claims our admiration, without in any degree diminishing our attachment to Vostermann, Pontius, Durer, Nanteuil, Masson, Audran, Woollet, or Strange.

We have here again to observe, as we did in allusion to Painting in water-colours, (see last Note to Art. 66.) that since Lithography is one of the "marvels" of our own times, and since those Lithographers who have raised it to eminence among the Fine Arts are our own living contemporaries, we forbear comment on their productions, and must leave to future Encyclopædists and biographers the duty of recording the ingenious and meritorious labours of a large class in this modern department of Engraving. In accordance, too, with that brevity to which our limits constrain us, we can make only a few remarks on the rapid progress of the Art, and state the several purposes to which Lithography has been applied.

Various applications of Lithography.

1. Imitation of chalk drawings.[*]
2. Imitation of drawing with a brush or hair pencil.
3. Imitation of wood-cuts.
4. Imitation of prints in chiaroscuro, for which several stone plates are employed.
5. Imitation of prints in mezzotinto.
6. Impressions in gold or silver.
7. Transfer of wood or metal Engravings and of letter-press to the stone for Lithographic impression.
8. Transfer of manuscript or *autography.*
9. Methods of *indentation,* where the stone is cut or engraved.
10. Method by the use of a point or needle, as in etching.
11. Method resembling aquatinta. (Art. 66.)

The ingenuity and perseverance of Senefelder are sufficiently manifest from the number and variety of these several applications of his discovery, all of them originating with himself. With the modesty of true genius he makes no boast of having perfected his Art, but in his book on the subject describes it as in an infant state, capable of being matured both in utility and beauty by the fostering industry of future hands. Senefelder being much better versed in *chemical* than in *pictorial* affinities, his labours refer to the sort of materials to be used rather than to the niceties and delicacies of graphic execution.

Bavaria, as a private soldier in the artillery, for which he was to receive a bounty of two hundred florins. With this small sum his enterprising spirit led him to imagine that he would ultimately bring his new Art into practice, and secure himself an honourable competency and reputation. Not being a native, however, of Bavaria, he was disappointed in this object, and was still suffering from the disappointment, when he met with a musician of the Elector's band, a former acquaintance, named Gleissner, about to publish some music. Senefelder induced him to produce it according to the new method. In less than a fortnight the composing, writing on stone, and printing of twelve songs was accomplished, and one hundred and twenty copies taken at the expense of about thirty florins. The entire impression in a short time sold for one hundred florins; thus leaving a profit of rather more than two hundred per cent. As a further encouragement, a copy of the Work was laid before the Elector Charles Theodore by Count Torring, and Gleissner received a present of one hundred florins, with the promise of an exclusive privilege for this method of printing. This privilege, in 1799, was at length granted to Senefelder for fifteen years, who now employed his two brothers, Theobald and George, and two apprentices, and no longer made a secret of the process. In 1800, a circumstantial description of it was lodged at the Patent office in London, and in 1803 with the Government of Lower Austria. M. Antoine André, an extensive music-seller, was among the foreigners who visited Senefelder's establishment, and a partnership was begun between them, in consequence of which Senefelder visited this Country about 1802 with M. Philip André, brother of the preceding; but the result was not answerable to expectation. During a residence, however, of seven months in London, Senefelder set himself to acquire a fundamental knowledge of Chemistry, in addition to that of several contrivances which he found subsequently valuable towards the improvement of his discovery. Some attempts in London at printing a few pen-and-ink sketches drawn on the stone by West, Fuseli, Stodhart, and other Academicians, were published: but no further progress was made, except in the application of the Art to military uses by the late Colonel Brown, then Quarter-master General, authorizing the purchase of the secret for £100 from Volweiller and Kergenrader, two Germans, who had been equally unsuccessful with André in their endeavours to introduce Lithography among the Arts in England. By the assistance of a pressman, whom these persons had employed, a Lithographic press was established at the Horse Guards; and the first map (a sketch of Bantry Bay) was produced in the beginning of the year 1808. Since that period Lithography has rapidly spread in this Country, not only for the official purposes, as well nautical as military, just mentioned, but for those also of the Fine Arts; and the establishment of Hullmandel in London has maintained a more or less successful rivalry with that of Englemann and Coindet at Paris, into which latter city it had been introduced by M. André in 1807, from whom the secret was purchased by several artists. We refer our readers to M. Englemann's *Manuel du Dessinateur Lithographique* (8vo. Paris, 1824,) for many able specimens, together with a very interesting exposé of the Art; and we only venture to observe, that if the French Lithographers have sometimes exceeded us in prints of this kind, our failure is attributable to a very superior command of the pen or crayon among the generality of French draughtsmen.

But to return to Senefelder. After endeavouring, with the assistance of his above-named brothers, to establish himself at Offenbach, where, in conjunction with André, he had availed himself of the Electoral patent, he found himself at his return from London necessitated to break up his partnership with André, and he removed with his brothers from Offenbach to Vienna, in hope of better fortune. At Vienna, in 1803, he succeeded in obtaining a similar patent throughout the Imperial States; but at Vienna, also, his expected resources failed him, and to clear himself from debts he sold his patent, in 1806, to M. Stein. Having thus honourably satisfied his creditors, he returned to Munich, where, in 1809, he received to his own great satisfaction, as well as that, we think, of our readers, the appointment of Lithographer to the Royal Commission of Customs. Thus removed, says M. Bartsch, from scenes of continued failures and crosses to a condition of comparative prosperity, he has employed his leisure to make fresh improvements in his Art, and to publish a complete manual of Lithography, in which (most disinterestedly, and, in a mercantile sense, to his own disadvantage) he has imparted every particular relating to the developement and practice of his invention.

[*] For some account of the peculiarities in this and the following processes, see Note (MM.) at the end of ENGRAVING.

Progress of the Art, notwithstanding the obstacles at its commencement.

The principal obstacles to the progress of this Art at its commencement have been, 1. The opposition of professional persons jealous of its advancement. 2. The disappointment of practitioners who, from inexperience, have failed in their first attempts. 3. The numerous impressions taken by incompetent printers, which have been regarded by the Public as specimens of the Art. All of these obstacles are surmountable by skill and perseverance, and disappear in proportion as the number of Lithographic establishments have increased throughout Europe. In 1809 there were six Lithographic printing-houses at Munich besides Senefelder's, notwithstanding his patent from the King of Bavaria. M. von Aretin and M. von Mannlich, Director of the Gallery at Munich, together with Professor Mitterer, of that city, have been early instrumental in leading the new discovery nearer to the precincts of Science. Professor Mitterer, in particular, has been distinguished for introducing a method of giving additional firmness to the Lithographic crayon, and by his invention of an improved Press, which Senefelder pronounces to supply every thing that can be desired in regard to power, despatch, and convenience. In 1807 M. Delarmé, of Munich, had founded Lithographic Presses at Rome, Venice, and Milan; and M. André introduced the Art at Paris; but it seems not to have obtained popular notice in France till after the more recent exertions of the Count Lasteyrie and M. Englemann in 1814, at which time it was adopted in this Country for despatch of business in most of our Government offices. From the Institution under Englemann at Mulhausen, also, in 1814, called *la Société Lithographique de Mulhouse*, Lithographic Printers were supplied for the Royal establishment at Madrid, for that of Messrs. Constans and Motte at Paris, and for that of Hullmandel in London. The city of Lyons also obtained its Lithographers from the same School. In Vienna, observes M. Bartsch, Senefelder's patent (obtained from the Emperor in 1803) was purchased by M. Stein. "A large Press in Berlin was established by Major von Reiche. Another has existed in Petersburg for many years, but is now particularly cultivated by M. von Schilling. The Art has reached even Philadelphia; and, what is yet more remarkable, has travelled to Astrakan, where it has met with a favourable reception."*

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* Lithography was introduced into Studtgard by *Strohhofer*, assistant of Charles Senefelder, brother to the inventor. He became acquainted with M. Cotta, and through him with M. Rapp, author of a Work entitled *The Secret of Lithography*, in which the importance of the Art to the Public was first fairly estimated. Since 1803 the Chemical Printing-press of M. Stein, and since 1816 that of M. Gerold, have been established at Vienna; but are surpassed, in the opinion of M. Bartsch, by that of the General Quarter-master Staff, under the direction of the Chevalier Joseph von Kohl.

ERRATA.

Page.	Column.	Line.
788,	2,	8, *for* Guiseppe, *read* Giuseppe.
788,	2,	24, *for* Raffaelli, *read* Raffaelle.
789,	1,	36, *for* Guiseppe, *read* Giuseppe.
792,	2,	9 from the bottom, *insert* dans *after* si.

NOTES ON ENGRAVING.

Notes on Engraving.

Note (A.)

When, in this manner, the device of the medal or coin has been given to the matrix, the artist proceeds to engrave the letters of the legend, &c. by means of small steel punches very sharp and well tempered. He finishes, by the same means, the mouldings of the border, the engrailed ring, &c. The matrix for coins being shallower than that for medals, is sometimes made, like the creux of a seal, (Art 2.) without punching, except for the letters. Coins have, consequently, less relievo than medals, and counters less than either.

The expression matrix, or womb, is sufficiently indicative of the ultimate process of coining, by which the *planchet*, or circular plate, of precious metal is received within a steel ring or collar of a corresponding diameter, and becomes forcibly stamped and moulded into its intended form by pressure on all sides against the steel intaglio. (See NUMISMATICS, p. 619.) By the foregoing statement it is by no means pretended that the first artificers would not be far inferior in point of mechanical accuracy and facilities (though not dissimilar in the general result of their process) to those of future Ages.

Intaglio, what.

Alberti's definition of *intaglio*, (see *Dictionnaire Italien-François*,) which appears to correspond with ours, (see *Miscellaneous Division*, for the words ENTAIL, INTAGLIO,) seems at variance with his other terms *intagliatore*, and *intagliare*, in reference to the graphic Art; signifying by *intagliatore* not only an Engraver *en creux*, but also *quel professore che intaglia in legno disegni per istamparli*, consequently signifying an Engraver, also, of *raised work*, or *camei:* while *intagliare*, the verb, he defines *formare chechessia in legno, o marmo, o altra materia col taglio degli scarpelli*, &c. It is to be lamented that artists are seldom linguists, and that with respect to a distinction, like this before us, so palpable and so decided between two methods of working diametrically opposed to each other, no absolutely precise terms are to be found. If we could muster up the same courage for coining English words as our brethren literate and illiterate of America, here would be a fine opportunity. We will only venture, however, to suggest the general use of a Shakspearian term, (see *Miscellaneous Division* for the verb CAVE,) and would recommend Engraving *en creux* to be called *caved work;* Engraving in relievo *raised work*.

To the reader who has opportunity, and is curious to see the modern advancement of the Art of coining by means of machinery, we recommend a visit to the Royal Mint of London. For some account of English coinage, we refer him to our Essay on NUMISMATICS, p. 643, 644. Mr. David Macpherson, in his able Work, the *Annals of Commerce*, vol. i. p. 266, enumerates various towns (to the number of more than eleven) in England to which the privilege of coining was restricted by King Athelstane. He remarks that at that time (about A. D. 930) artificers would of course be found in each town capable of working in silver and engraving the dies. "We find," says this author, "even in the more remote Kingdom of Scotland at this time a case for containing the Gospel at St. Andrew's. It was covered with silver, most probably by a native artificer, and had two Latin verses inscribed upon it by a Scottish Engraver."

Die-Engraving in England.

A. D. 930.

A. D. 1207.

Canute increased the number of coining places to thirty-seven. In A. D. 1207, during the reign of John, Mr. Macpherson enumerates sixteen cities and towns for this purpose, but subjoins in a note, that so many mints were established in many other places that a complete list would perhaps be impossible. The Yutes, Saxons, or Angles, surpassed all the other Northern nations in the Art of Coining: an important point in the progress of civilization to which the Scandinavians had not attained in the Xth Century. In the reign of our Ist Richard, and of John, the Germans were distinguished for this Art. Those Monarchs, with the design of improving the coinage of England, sent for artificers from the East-Country, or Germany, called Easterlings, and hence the well-known term *sterling*, applied to English money ever after. The coinage till Edward III. was chiefly of silver. In that reign, (Jan. 22. 1344,) money of three sizes was ordered by the King and Parliament to be coined of gold. *Annals of Commerce*, vol. i. p. 283. 307. 374. 530.

A. D. 1344.

Note (B.)

The burin described.

A description may be proper here of the instrument itself. It is of steel, more or less tempered according to the material to be engraved by it. For Engraving on steel, for example, the burin must be of softer metal than for working on copper: because if too hard, the point will snap and break off continually. The Italian name *bolino*, or *bulino*, for the graving tool, may, as a diminutive, be possibly derived from the Teutonic *beyel*, *beil;* Belg. *byl;* A. G. *bill*, which Skinner translates *securis* rostrata; denoting the well-known instrument of the woodman, called a *bill*-hook. To the beak of a long-*billed* bird the *bolino* certainly bears remarkable resemblance; as does its wooden handle to the shape of the bird's head. Also the ancient *bolla*, *bulla*, or seal, which would doubtless exhibit the work of the *bolino*, or graver, may have the same common Teutonic origin. (Evelyn, *Sculptura*, p. 22.) Likewise *bill*, or *billet*, for a small engraved tablet or note. (See *Miscellaneous Division*, *in loc.*) That the French name *burin* for the graving tool, as well as the Spanish and Portuguese *boril* or *buril*, have the same etymological source with the Italian *bolino* or *bulino*, will be admitted, from the frequent substitution of *r* for *l*. (*V.* Skinner, *Prolegomena*, *in loc.*) The burin may be considered as a kind of chisel, having its handle rounded, so as to lie conveniently in the hollow of the hand. Its other extremity, or blade for cutting lines in the metal, is a small quadrangular steel bar, from three to five inches long, of which a transverse section would sometimes be square, but would commonly have the shape of a lozenge, with two equal and two unequal angles. One end of this bar is firmly fixed in the handle, the other end is sloped to a point at one of its edges, and the angle both of the slope and of the edge made more or less acute in proportion to the depth or to the breadth required for the lines on the metal. The instrument is held as shown in plate i., while its point with its slope upwards is inserted into the copper, silver, or other surface, and forced forward in a direction nearly parallel to the plate. During its passage along the metal, the burin cuts out a thin, thread-like portion of the engraved substance, which, like the shaving before a carpenter's plane, curls up before the edge of the tool. The thread of metal varies more or less in thickness according to the breadth and depth of the line or furrow ploughed by the graver, and there will always be left on the side of this furrow a certain portion of the metal which has been forced up, and remains in a rough state above the surface. This is called the *burr*, and must be smoothed off by means of another steel instrument, termed the *scraper*, (see plate i.,) in a prism-like form, having three sharp edges. The scraper is also useful for erasure of errors. After the effectual application of it the erroneous lines entirely disappear, but an excavation, sometimes considerable, will have taken place in the scraped part; which must again be restored to a level with the surrounding surface, and beaten out by the strokes of a small hammer on the back of the plate. It is evident, with reference to the future print on paper, that the more deeply the lines are engraved on the metal, the greater must be the quantity of colour required to fill them, and consequently, the richer will be the impression. The Engraver, therefore, varies the form of his burin according to his fancy and the nature of his work. If deep, narrow lines are to be engraved, the blade used is proportionally thinner, according to the depth required, and its point more sloping, according to the fineness of his lines. On the other hand, if broad, shallow lines are to be drawn, the blade used is of proportionate thickness and of rectangular appearance, while the slope at its point must terminate less acutely. It is asserted by Adam Bartsch, in his Guide to Engraving, (*Anleitung zur Kupfer-stichkunde*,) 8vo. Vienna, 1821, that plates wrought with high burins (by which he means such as terminate in an acute slope) produce spirited, rich, and splendid impressions; whereas those works on which only obtuse-angled blades have been employed, come out, even in the proofs, grey, flat, and inanimate. "The commonest burins," observes this intelligent artist and useful writer on Art, "are neither quite rectangular nor very rhomboidal, but are what Engravers term half-high, *i. e.* with an angle of 70°. The burin during the operation of Engraving requires to be sharpened frequently on a fine whetstone, used with oil: for if its point and edge be not perfectly sharp, the operator can neither produce a clean nor a fine stroke, nor enter the copper to a sufficient depth. Sometimes this instrument takes a curved form, with the concave side of the curve towards the plate. This sort of burin is used for dotting. Note (GG.) Otherwise the curve takes, in general, a quite opposite direction, namely, with its concave side upwards, in order that the instrument may pass with facility along the copper, and that such lines as terminate insensibly in a point, may be well executed. Sometimes its lower edge (*viz.* that employed next the metal) is rounded. Sometimes it is chisel-like and squared." vol. i. p. 5—7. (See plate i. for sections of different gravers.)

The size and angle of the burin regulated by the kind of work to be executed.

Our English name for this instrument takes its derivation, like the German *grabelstich*, from the Greek γράφω: yet it is remark-

Notes on Engraving.

able that no Greek name for it is extant similarly derived. Its Greek appellatives are γλυπτήριον, or ἐγκολαπτής. It may here be worth observing that in our authorized translation of Scripture, the expression "graven image" should frequently be "molten image."

Note (C.)

The Ancients must have known fully as well as any artist of the XIVth or XVth Century, or of our own times, the difference between the seal and the impression; between the die and the coin; between a figure or device sunk and hollowed into any substance, and the same figure or device raised and in relief. And yet the Ancients, like their successors, seem to have used their terms of Art at random. The same word γλύφω, (in the Septuagint translation of פתח,) which literally means *I plough up*, is used to express the action of the graver, whether employed for cutting seals and signets, (*Exod.* xxviii. 9—11.) or for carving images and works in relief. (*Judges* ii. 2. 2 *Kings* xxi. 7. *Habb.* ii. 18.) In *Ezek.* iii. 9. of the Septuagint version, the verb ὀρύσσω, *I dig*, is used instead of γλύφω, *I plough*, and the substantive βόθρος, *a ditch*, instead of γλύμμα, *a furrow*, to express the operations of the graver. See our *Miscellaneous Division* for the Etymology of Grave.

Indistinctness of terms in this Art.

The Ancients also must have known that an impression upon any substance is the reversed image of the seal, die, or other instrument from which the impression has been taken, and not only reversed with respect to the direction of the lines of the impressing surface, but reversed also with respect to the workmanship (raised or sunk) of the surface itself. Thus of a diagonal drawn on the impressing surface from left to right they could not fail to discover the impression to be from right to left. Thus also they would ascertain, (without the exercise of extraordinary perspicacity,) that the impression of a relievo or cameo would be *en creux*—as in the operation of sinking or punching a die; and *vice versâ* they would see an opposite result in stamping the coin. They would moreover be equally in the habit of taking both kinds of impression, and would be familiar with the different substances most suitable for receiving impressions. Not only metals for this purpose, as in coins, medals, and counters; but terra sigillaris, cement, paste, and wax, would be constantly in requisition. (See Beckmann, *Hist. of Inventions*, on the Article *Sealing-wax*, 8vo. vol. i. p. 208.) The Roman potter *stereotyped* his vases. The Greek or Roman slave-owner branded his slaves; the Greek or Roman conqueror his captives. The soldier, too, whether of Greece or Rome, received a stamp to mark him for a military conscript.

On sait, says M. Jansen, *que les Romains avoient coutume de marquer leurs vases. On trouve une infinité de ces vases de terre chargés d'inscriptions, sur lesquels on peut voir les recueils d'antiquités de M. le Comte de Caylus.* Vasa signare *veut naturellement dire* cacheter des vases, des bouteilles, *et c'est ce qui se pratiquoit. On mettoit le nom du consul sur le bouchon de la bouteille, pour faire voir de quelle année étoit le vin qu'on y conservoit, &c. De l'Invention de l'Imprimerie*, Paris, 1809, 8vo. p. 190. In the Hamiltonian Collection above alluded to, at the British Museum, a variety of stamps or brands found in the ruins of Herculaneum and Pompeii is preserved. See the IId Volume of Strutt's *Dictionary of Engravers*, to which, among other plates, is prefixed one (plate v.) containing six representations of this ancient kind of letter-press, the same size as the originals, which latter have the appearance of being first cast, in a kind of mixed metal resembling brass, and afterwards repaired or sharpened with the chisel. The letters in five of the examples given are raised from their ground like our metal types, and consequently would print black; in the sixth example they are *en creux*, (Art. 6.) and consequently would print the letters white, if an impression of the stamp were given with ink upon paper. Upon one, which is in the form of a fish, the Greek word ΠΑΝΦΙΛΙ in reverse is distinctly legible. Another takes the form of a shield; a third that of a sandal, &c. Some have inscriptions at full length; others only monograms. In one instance, three lines of *stereotype* occur following each other. So that the discovery of Printing was actually made, though not practised, as it should seem, upon paper, nor improved upon by movable types, and charged with ink. "Mankind," says Mr. Ottley, referring to an observation of the Abbé Lanzi, "have walked for many succeeding centuries upon the borders of the two great inventions of Typography and Chalcography without having the luck to discover either of them; and the stamps of the Ancients and the seals of the low Ages appear neither to have had any influence upon the origin of those Arts, nor to merit any place in their History." *Hist. of Engraving*, 4to. 1816, p. 59. Other learned persons look upon the *formæ literarum* of Cicero, (*de Naturâ Deorum*, lib. ii. 37.) by which he certainly meant separate letters made of metal, as a sufficient hint to the first type-founders. Others more fancifully trace the same idea to the Sybil's leaves, which

Specimens of ancient stereotype.

Manent immota locis neque ab ordine cedunt,

until the wind separates and scatters them. Virgil, *Æneid*, lib. iii. l. 447.

Impression. Its antiquity.

The reader, possibly, will recollect the words of our Form used in Baptism. The baptized Christian, on being received into the society or communion of the Church, is signed with the sign of the cross in token of having entered the service, and of becoming an enlisted soldier of Christ. See Wheatley on the Common Prayer, ch. vii. 7. p. 334. Vegetius, lib. ii. cap. 5. *De re militari*, says of the *tirones* or young Roman conscripts, *victuris in cute punctis milites scripti et matriculis inserti jurare solent:* thus signifying, according to the received sense of the passage, that previously to their *sacramentum*, or oath of allegiance, they received some outward indelible mark, and were enrolled or matriculated. Aetius, in lib. viii. c. 12. describing the στίγματα, says, στίγματα καλοῦσι τὰ ἐπὶ τοῦ προσώπου ἢ ἄλλου τινὸς μέρους τοῦ σώματος ἐπιγραφόμενα, οἷα ἐστὶ τῶν στρατευομένων ἐν ταῖς χερσίν. Lipsius conjectures that this mark upon the hand of the soldier might have been the Emperor's name, but professes his ignorance of the nature of the stamp. The branding of slaves is distinctly and fully mentioned in Juvenal, *Sat.* xiv. 21—25, and not to multiply authorities, Cicero, *de Officiis*, lib. ii., mentions, *Barbarum* compunctum *notis Threiciis*; to whom a little after he applies the Greek term *stigmatiam* (στιγματίαν) for a branded person. Captives, also, were marked in this manner: as was the fate of some Athenians (*v.* Plutarch in *Niciâ*) taken captive in Sicily, and branded on their foreheads with the sign of a horse by their conquerors, στίξαντες ἵππον εἰς τὸ μέτωπον. *Vid.* Stephani *Lex. in voc.* στίγμα. These *stigmata* seem to have been variously made, perhaps often by puncture or tattooing, like those with which our common sailors mark their breasts and arms. The practice of stigmatizing seems to have prevailed through many Ages down to the present, as well for honourable distinction as for a sign of punishment, degradation, or servitude. Very nearly allied to this practice was the custom of painting the skin among our forefathers of Britain; under this form it prevailed, according to Mr. Macpherson, almost down to the Norman Conquest, and among the Saxon Nobility. (See *Annals of Commerce*, vol. i. p. 298, where the worthy North British Chronicler complains, in a note, of the erroneous application in England of the Roman term *Picts* to our Northern ancestors *only*.) For an amusing description of the mode of exercising this *branch of Art* at present in New Zealand, see Mr. Augustus Earle's *Account of Nine Months' Residence* in that Country, 8vo. Lond. 1832, p. 136—139.

Ancient practice of branding or stigmatizing.

It has called forth the surprise of all who have explored antiquity on this subject, that the Ancients, so near as they were to the discovery of taking impressions with ink upon paper or parchment, were never stimulated to contrive this ready method of multiplying copies, and thus of preserving their inestimable literature. The story of the ingenious Spartan King Agesilaus, tempts every modern reader of Plutarch to believe that the elements, at least, of the Art now under our consideration were not unknown to the initiated and civilized of Asia and Greece. That monarch, during a campaign in Egypt, whither he had repaired to the succour of the Egyptian King, found himself opposed to a force so disheartening and so disproportioned (two hundred thousand men) to the army under his command, that for the purpose of reanimating his brave and superstitious troops he had recourse to the following expedient. A sacrifice had been ordered, at which, while the Priest was preparing the victim, Agesilaus contrived to withdraw a moment, and to write within the palm of his left hand the characters HKIN, being the reverse of NIKH, the Greek word for victory. Returning to the altar at the instant of opening the body of the immolated animal, the King immediately took up the liver of the victim, and placing it in his left hand, seemed for a while lost in abstraction. All at once awaking from his pretended trance, and looking upon the sacred object, he affects surprise, and produces with seeming ecstasy the word NIKH imprinted on it, as a propitious answer from the Gods. The astonished and delighted bystanders hail the omen, which is spread instantly through the rest of his army, and actually animates them to the victorious achievement of his next battle.

Ancient hint of impression taken by Agesilaus.

If this anecdote related of the Lacedæmonian hero of his day (his day was about 400 years before the Christian era) be true, we are disposed to think that, great as was the genius of King Agesilaus, and simple and unlettered as were his Spartan people, he might have learnt sufficient hints for this contrivance in his many visits to Asia Minor, Persia, and Egypt. But if, on the other hand, this story be only an amusing fiction; and if the relater of it in less than 500 years afterwards (Plutarch was born about A. D. 50) has quoted, which however there is no reason to suspect, a traditionary fable, we cannot believe that Plutarch himself, or any except the

Notes on Engraving.

most stupid of his readers, should never have heard or thought of some experiment for taking impressions with ink, which would imitate, or at least might verify, the ingenious trick imputed to Agesilaus.

From the original we extract the following portion: *ἐστρατεύθη ὁ Ἀγησίλαος εἰς Αἴγυπτον μεταπεμφθεὶς ὑπὸ τοῦ βασιλέως Αἰγυπτίων ἐπὶ μισθῷ.—Ἐπεὶ δὲ τοὺς παρ' αὐτῷ παραστήσεσθαι μέλλοντας ἑώρα δεδιότας τὸν ἐπιόντα κίνδυνον διὰ τὸ τῶν πολεμίων πλῆθος (εἴκοσι γὰρ ἦσαν μυριάδες) καὶ τὴν τῶν περὶ αὐτὸν ὀλιγότητα, πρὸ τῆς παρατάξεως ἔγνω προθυμήσεσθαι ἀσυνειδήτως τοῖς ἄλλοις· καὶ ἐπὶ τὴν ἀριστερὰν ὑπεστραμμένῃ τῇ χειρὶ* ΝΙΚΗΝ *προσέγραψε· λαβὼν δὲ παρὰ τοῦ μάντεως τὸ ἧπαρ, ἐπέθηκε μὲν ἐπὶ τὴν ὑπογεγραμμένην χεῖρα· κρατῶν δὲ ἐφ' ἱκανὸν χρόνον ὑπέφαινε, διασταλμὸν καὶ προσποίησιν ἔχειν ἀποροῦντος. μέχρι τῷ ἥπατι συνανεληφθέντες, ἐτυπώθησαν οἱ τῶν γραμμάτων χαρακτῆρες· καὶ τότε τοῖς συναγωνίζεσθαι μέλλουσιν ἐδείκνυε, φάμενος τοὺς θεοὺς διὰ τῶν γεγραμμένων ἐκφᾶναι* ΝΙΚΗΝ. *ἀσφαλὲς οὖν τεκμήριον δόξαντες ἔχειν τοῦ κρατῆσαι ἐθάῤῥησαν πρὸς τὴν μάχην.* Plutarchi *Laconica Apothegmata. Agesilai, ad fin.*

Note (D.)

Importance of good handling.

" Although the Engraver," says M. Bartsch, " has not the Painter's power of characterising different bodies by the appropriate colours of each, he possesses abundant means of representing their surfaces so intelligibly, that hard bodies shall be distinguished from soft, smooth from rough, shining from dull, and that the copper-plate may often rival in truth, fidelity, and beauty the coloured painting. For this purpose attention must be given to the different modes of handling as well with regard to the choice of strokes (fine or broad, deep or shallow) to be engraven, as with regard to the judicious direction and distribution of them. If this handling be entirely of the same sort throughout the plate, such a work will evidently possess less distinctness, and strike the eye less forcibly than a work in which each substance of the composition is appropriately executed, leaving us in no doubt of its individual character. An Engraving is always defective when, through the unintelligible handling of the graver, certain bodies represented are only to be guessed at by their outline, or by merely the light and shadow thrown upon them. The various substances and objects engraved, such as carnations, cloths, silks, metal, stone, &c., ought, with very few exceptions, to be distinguishable from each other by the handling alone." It is, therefore, by no means a matter of indifference, whether the lights and shadows are represented by lines drawn at random, but the strokes or dots used to mark the surfaces of different bodies must alternately be straight and curved, smooth and rugged, free and stiff, charged sometimes with more, and sometimes with less colour, (literally rich and meagre, *genährt und mager*,) sometimes delicate, sometimes strong, sometimes in broad and sometimes in slender lines, but always judiciously adapted to the form of each body represented, and to the natural direction of muscles, folds, and every kind of surface raised or hollowed. *Anleitung zur Kupferstichkunde*, vol. i. p. 83. sec. 252, 253. ed. 1821.

Iandling aries with he kind of urface reresented.

Sharp, clean strokes serve to represent polished surfaces; rough, wavy, crooked, and abrupt strokes and dots are adapted for dull and uneven surfaces. These strokes may be so placed as not to cross each other, in which case they are usually termed a single course of lines. In other cases they intersect and form various angles according to the peculiarities of the surface represented. One course of such shadings conduces to smoothness. Two or more courses represent, by their crossings, roughness or abruptness. One course of lines, cleanly and evenly cut, produces the highest degree of smoothness, polish, and glitter. A triple course of wavy or abrupt strokes produces, on the other hand, the highest degree of roughness. Between these two extremes lie innumerable varieties of handling which the genius of the artist must select and arrange. A double course of lines forming squares or trellis-work, that is, crossing each other perpendicularly, present a harsher and less agreeable effect to the eye than such an arrangement of courses as will form whole or half lozenges. This latter treatment is preferred for representing soft bodies, and is more or less departed from in proportion to the comparative roughness of the part delineated; it is, therefore, a treatment seldom introduced for drapery, but is successfully employed for the surface of the human skin, to which, equally by painters and Engravers, the same artistic synonymes are applied, *viz.* the flesh, the naked, or the carnations. On the subject of hatchings M. Bartsch draws a comparison between the works of Gerard Edelinck and Scheltius von Bolswert to the advantage of the latter, who, he conceives, should rather rank before than after Edelinck as far as regards manual dexterity in handling the graver, and who has executed some plates with such lightness and freedom as leave nothing to be desired. " But this freedom," adds the author, " has its origin in a judicious direction, union, and ultimation of the lines; important particulars in which Edelinck was remarkably deficient." The most expert Engravers have committed errors as to the location of their hatchings, by carrying them in a trellis-form over the whole plate. And, perhaps, the greatest evil resulting to the Art has been the unjust blame attached by obstinate and prejudiced people to the burin itself, which has been accused of producing, even in the most experienced hands, an effect of stiffness. To the surprising works of Edelinck was the palm of excellence fairly adjudged, for entire correctness of outline, perfect observation of light and shade, and clean execution; and yet some stiffness was to be discovered, a fault, it was conceived, not attributable to want of judgment in the artist, but inseparable from the use of the graver. This apparent stiffness, M. Bartsch contends, has its rise solely in a careless and injudicious arrangement of the strokes; in an over-anxiety to produce a metallic lustre through the exactness of their position; in the monotony also of their effect, and too frequent repetition of the same class of lines. *Ibid.* p. 97. sect. 284. and p. 94. sect. 278.

Handling.

Note (E.)

Handling for draperies, velvet, silks, &c.

The same handling serves to engrave watered damask, and other shining rich silks, especially where dark flowers are thrown up over a light ground; only here the lines must run more closely together, and the intermediate strokes be drawn only in the shadows instead of being carried through to the light. Examples of beautifully executed velvet are to be found in portraits engraved by Wille, as well as remarkable specimens of flowered damask. M. Bartsch quotes also Wille's Engraving of " Cleopatra" after Gaspar Netcher, as a splendid imitation of white satin, so also is his " *Instruction paternelle*" after G. Terburg.

Dark stuffs, how to be distinguished from light ones; thin draperies from thick, &c.

Various other draperies used for dress are likewise worked in so many different patterns of Engraving suited to each. But this diversity does not so much consist in selecting the strokes as in placing them more or less apart; or as in expressing accurately and suitably by the direction of them the shape of the lights and shadows which they serve to delineate. Draperies light-coloured, or perfectly white, should, indeed, be represented by strokes of delicate fineness, while others darker or quite black require stronger lines. But a distinction is also to be made between thick stuffs, such as broad-cloth and other woollen draperies, and finer materials, such as linen, taffeta, and other silken fabrics of thin texture; by following with the burin the large round folds of the former, and the narrow sharp plaits of the latter, rather than by any difference in the application of the instrument.

It hence appears that the Engraver who works according to rule, is not always obliged to vary his handling (Art. 15.) with every change of drapery, but that in some cases the form of the lights and shadows in his original will suffice, with judicious management, to give his work an air of truth and nature. " But it is evident," adds M. Bartsch, " that no expertness in the artist can enable him to represent with the burin such draperies as have been badly painted, and are imperfect either in respect to shading or outline. Defects in many Engravings are unjustly charged upon the Engraver, whose only fault, perhaps, is a too faithful copy of his original."

Variety likewise in the folds.

If a dress of white stuff and one of white linen be worked with the same class of strokes, yet a difference between the two textures will be readily discoverable by the characteristic disposition of the folds. The folds of woollen cloth are few and large: those of linen, on the contrary, are numerous, and hang almost perpendicularly. (See Painting, last note to Art. 264.) Fine linen, in Engravings, bears a near resemblance to taffeta, for both of them hang in small folds. But a nearer examination will show the folds of taffeta to be sharp, abrupt, and flowing; those of linen rounder, and hanging more perpendicularly. The same arrangement, too, of lines is adapted to satin as to taffeta and linen; yet the former of these materials (satin being thicker and heavier than the others) is readily distinguishable by hanging in fuller, larger folds. Satin, too, is easily discernible by its gloss, which can be imitated only by a strong contrast of light with darks. Taffeta exhibits very little of this appearance, and linen still less. For specimens of judicious handling, in representations of fine white linen, we are referred by M. Bartsch to a boy holding a torch in Jacob Schmutzer's Engraving of " Theodosius," after Rubens: in Wille's " Devideuse" and " Liseuse," both after Gerard Douw. Wille, he observes, has been less happy in his representation of linen in his " *La Tricoteuse Hollandoise*," after F. Mieris. The strokes for the linen should have been more delicate, instead of the handling being similar to that of the other draperies. See *Anleitung*, &c. vol. i. p. 88. sec. 265—267.

Specimens of good handling

Thick and rough drapery how expressed.

For thick and rough woollen stuffs, waving lines may be used with advantage: they serve for a groundwork, and form the first and narrowest series of strokes; and are afterwards crossed by two series of other strokes cleanly cut and wider apart. The smaller the waves of the foundation lines or groundwork, the rougher and more woolly will the stuff appear. The coat of Wille's "*Cuisinier Hollandois*" after Metzu, exemplifies in perfection this kind of handling. For carpets and other woven materials of still greater roughness, small detached strokes resembling segments of circles are substituted for the waving lines. Their effect may be seen in Wille's admirable carpet of "*L'Observateur distrait*," after Mieris.

Note (F.)

Handling of uneven ground.

In order to increase this effect of uneven and rough ground, small dots are introduced with the graver into the interstices of the hatchings. They must be placed quite freely and irregularly, and sometimes are even attached to the lines. As an example of this effect, M. Bartsch refers to a small space of excellent foreground in the Engraving before alluded to, (the "Theodosius" of Jacob Schmutzer,) and complains of Woollett and some of his followers for representing earth by a peculiar and quite different method which he allows to be pleasing, but denies to be natural. "The whole handling," says he, "is too broad. The strokes employed have too much of a serpentine character, and the whole effect is overlaboured and forced. See, for example, Woollett's celebrated Engraving, the 'Death of General Wolfe,' as well as most of his other works." *Ibid.*

Specimens from Schmutzer and Woollett.

Trees and plants.

The stems and leaves of trees and plants require also free touches. In trees, the bark of the trunk has great similarity with the unevenness of broken ground, consequently it requires nearly the same handling. But as the bark is hard, and, in many trees, smooth, the strokes must be finer, and proportionably closer than for ground.

Stony substances.

When stones are in a natural, unhewn state, and necessarily have a rough surface, they are engraved in the same manner as ground. For sharp and craggy objects the strokes ought to be frequently discontinued and broken. On the contrary, smooth stones must be expressed by straight lines cleanly and evenly cut in proportion to the degree of smoothness. In Architecture, the curved lines which shade round objects, such as pillars, &c., must be drawn carefully in good perspective. Each must tend to the centre of the vanishing line of its plane: namely, to the centre of the picture whenever the pillar or other cylindrical object has its axis parallel to the perspective plane. (PAINTING, Art. 118, 119, 120.) Upon entire standing columns the shading should, as much as possible, be effected by perpendicular strokes. If hatching be attempted, it should be at right angles to the first series of lines, and also much wider and thinner. Architectural work should never be black, except in representing old and ruinous buildings. New and handsome edifices built of stone or white marble, reflect light and colour on all sides, and cannot, like other substances, exhibit dark shades.

Buildings.

Distances. Water.

Distant objects, as they approach the horizon, must be handled very tenderly. Calm and still waters are represented by strokes parallel to the horizon interlined with finer strokes, and having some parts untouched, where gleams of light appear, in reflections from the watery surface. Objects reflected from the water, which stand at a small distance from it, or on its banks, are expressed by retouching the horizontal strokes more or less forcibly, according to the nature and position of the reflected object. Sometimes these reflections may require lines even perpendicular to the horizon. To represent agitated waters, such as waves of the sea, the first course of strokes should follow the figure of each wave, and may be interlined: the second course, or cross strokes, ought to be very lozenge, *i. e.* ought to cross the other at a very acute angle.

Note (G.)

It is not enough that shadows and reflected lights be merely expressed by an alternation of broad and fine strokes; or by hatchings that contain one or more courses of lines. The courses themselves must also be so drawn as to show at once the requisite degree of roundness, protrusion, or prominency in the body they are designed to shade. In all hatchings, the first layer or foundation must be of broader lines than the rest, firmly drawn, and more closely ranged: the second rather thinner, and further apart: the third still more delicate. The first, being employed to describe the course of the muscles and the forms of bodies, should be marked the most strongly and decidedly. The others which cross it are added only to give more *colour* to the figures or bodies in question: the first only delineate; the others paint: the first serve for determining the form; the others are serviceable in imparting the due effect of chiaroscuro. To give the effect of distance, the detail of distant objects must have less distinctness as they recede from the eye: their minute parts should be omitted: their larger divisions shaded indistinctly and *in masses*. Or again, when the principal course of lines, in marking the direction of the muscles, and of folds in drapery, are drawn more faintly as they approach lights and reflexes; but deepened and made to swell out in positive shadows: the result will be both *warmth* and *richness* of colour. This gradual enlargement of lines in places that verge gently and gradually into shadow spares the necessity for a second or sometimes a third series, which must otherwise have been wanted for producing the required effect of colour, but would not have produced it so agreeably.

First layer of all hatchings to be broad.

Handling.

Contrivance for determining the direction of the first hatchings.

Evelyn in his *Sculptura*, p. 108. mentions an ingenious expedient, for which he refers to the Treatise of Du Bosse to assist the Engraver in determining the direction of his hatchings according to the form of any engraved object. He supposes a square frame, such as we have represented in plate i. fig. 7, to have several threads or wires tightly stretched across it, parallel to one side, and a single thread so placed as to cross the others perpendicularly about the middle, and to show the direction of square hatchings. A model of the object to be engraved is then placed in the sun, and the frame is held between the sun and the model in such a position that the shadows of the parallel threads may fall upon it. The shadows take a direction perfectly conformable to the surface of the figure, and enable the artist to adapt his lines with similar fidelity to the representation of a similar surface.

Specimens of bad handling.

To convince any one (Bartsch, *Anleitung*, &c. vol. i. sec. 261. p. 95) of the disagreeable effect occasioned by a departure from this rule, let some Engraving, the work of the Italian artist Giovanni Marco Pitteri, be examined. This Engraver, in many particulars a respectable one, finished most of his plates by means of one course of lines alone, which run parallel from the top to the bottom of the point over almost all the shades and lights; and are strengthened in the shadows as occasion requires. His knowledge of chiaroscuro enabled him to mark some apparent distinction between the parts of his picture represented retiring and other parts represented in relief. But on examination, their markings will be found in most cases exceedingly feeble and inefficient, merely from the lines which contain them having a contrary direction to the form of the engraved object. Another remarkable offender against this rule, who has almost totally disregarded carrying the strokes of his burin in a direction conformable to his outline, is an eminent French artist, Claude Mellan. Most of his Engravings are executed by a single course of parallel lines passing over the whole plate, and expressing the shadows by being made in some parts stronger or broader, and consequently nearer to each other. A head of Christ by this artist is executed with even a single series of spiral lines commencing at the tip of the nose. "We may easily imagine," says M. Bartsch, "without seeing this print, the disagreeable, constrained effect of this endless continuity of curves, quite independent of the several given forms to be represented by them: not to mention the flatness of the shadows, the unpictorial monotony, and the universal confusion inseparable from such a burlesque upon the Art of Engraving." The severe justice of this criticism we are not prepared to dispute: but we are at the same time wickedly inclined to suspect, that had these offenders been of the German or even of the Flemish School, M. Bartsch would have been more merciful to their ingenious eccentricities.

Hatchings either lozenge or square, [illegible]

If the first and second course of lines cross each other in such a manner as to form squares, the third course or series should make with one of them a lozenge. Or, if the first two form a lozenge the third should make a square. The latter method of handling has a superior effect, and is consequently preferred to the former. Lines for drapery must vary according to the shape of the folds. The first course must here be used (as for flesh) to delineate the form and direction of the folds. If this one course be insufficient to characterise them properly, a second or even third series must be employed; each always less marked than the course which preceded it. Lines in a naked or other figure which terminate at right angles with its outline have a very bad effect; all such lines should take a sweeping direction, conformable to the outline, and should lose themselves in it softly and imperceptibly. Respecting distant objects, M. Bartsch recommends that in order to give them less distinctness, all lines in the distance should be delicate, and its outlines as well as shading less defined. Shadings off must be very gradual: objects, in proportion as they tend to the horison, must have finer and thinner strokes: the smaller portions of distance less and less marked; the larger portions more and more indistinctly, and in masses. Harshness is to be avoided generally throughout any picture by due attention to keeping and harmony. (See PAINTING, p. 576.) Much depends on the strength of the lights. Where strong lights appear, the shadows are more marked and bolder: but where the light is feeble they have greater softness. The chief difficulty, therefore, is to avoid harshness in strong lights, because here all shadows terminate abruptly.

Other rules for the direction of engraved lines.

Note (H.)

See the remarkable passage in that most ancient relic of patriarchal literature, the Book of *Job*, ch. xix. ver. 23, 24. quoted by

Reference in Job. xix. 23. 24. to ancient Engraving.

Also in Isa. xxx. 8.

Chinese tablets.

Evelyn, (*Sculptura*, p. 20.) and after him by Strutt, (*Essay on Origin of Engraving*, p. 8.) of which the latter gives the following literal version. *Who shall give* (or ordain) *now, that my words shall be drawn* (or written:) *who shall give that in a book*, (or memorial,) *they shall be delineated: that with a pen of iron and lead they shall be hewn out in the rock for ever?* Better explained by Bishop Patrick's paraphrase: Oh that my protestations and appeals might remain upon record, registered in the public acts, and that they might be graven upon a plate of lead with an iron pen, nay cut into a rock or marble pillar, to continue to all posterity! Of this passage in Job, Evelyn observes, that it "comprehends all sorts of ancient writing or Engraving," the use of the stylus and of books, the use of plates and of stone. The Septuagint version of it is as follows: Τίς γαρ ἂν δῴη γραφῆναι τὰ ῥήματά μου, τιθῆναι δὲ αὐτὰ ἐν βιβλίῳ εἰς τὸν αἰῶνα; ἐν γραφείῳ σιδηρῷ, καὶ μολίβδῳ, ἢ ἐν πέτραις ἐγγλυφῆναι. To this we add another quotation from a much later scriptural authority, *Isaiah*, ch. xxx. ver. 8. Νῦν οὖν καθίσας γράψον ἐπὶ πυξίου ταυτα καὶ εἰς βιβλίον ὅτι ἔσται εἰς ἡμέρας καιρὸν ταυτα καὶ ἕως εἰς τὸν αἰῶνα. *Now go write it before them in a table*, &c. Here the word πυξίον, which we translate table, means *tabella scriptoria*, or more literally, a tablet of boxwood, being made out of the πυξίς, or box-tree. Πυξὶς seems as fair a derivation for our English or Saxon word Box: as papyrus for *paper;* or as βίβλος (another name for papyrus, the Egyptian plant or reed that furnished paper) for *bible. Liber*, in Latin, took its name likewise from the material used for writing on; *viz.* the inner bark (*liber*) of trees. Adams, *Rom. Ant.* p. 506. We have already observed (see *Biographical and Historical Division* for CONFUCIUS, p. 491.) upon the custom, probably familiar to the Chinese, of using the bark of trees before the invention of paper: and have alluded to manuscripts of the kind preserved in several Libraries of Europe. M. Klaproth, in his *Tableaux Historiques*, 4to. 1821, dedicated to M. Humboldt, thus chronicles the acts of a Chinese conqueror and Emperor, Thsin-chi-houang-ti, whom he styles *fondateur de la dynastie Thsin qui a donné à la Chine le nom qu'elle porte dans l'occident. Il eut sans cesse à lutter contre les grands qui auraient voulu de nouveau morceler l'empire, et qui n'oubliaient rien pour rétablir le système féodal des Tcheou en s'appuyant sur les anciens livres et sur l'histoire. Excédé des représentations importunes et répétées, qui contenaient des passages et des principes extraits de ces livres, il commanda de brûler tous les anciens ouvrages historiques, et principalement ceux de Confucius, qui avoit vécu environ* 300 *ans avant lui. Ces ordres furent exécutés avec la plus grande rigueur. C'est cette mesure violente que les lettrés Chinois n'ont jamais pardonnés à l'illustre fondateur de la nouvelle Monarchie. Cette exécution est la cause il est vrai de l'état incomplet dans lequel les notions historiques sur l'antiquité Chinoise nous sont parvenues. Néanmoins elles n'ont pas été tout à fait perdues; car dans un pays où l'écriture est si répandue, il était presque impossible que toutes les copies d'ouvrages universellement respectés pûssent être anéanties, surtout à un époque où la matière sur laquelle on écrivait était très durable. Les caractères étaient en effet gravés avec un stylet sur des tablettes de bambou, ou bien ils y étaient tracés avec du vernis, d'une couleur foncée. Cependant si l'empereur des Thsin a fait essuyer une perte irréparable aux sciences par la destruction des livres anciens; son grand général Moung-thiau les en a amplement dédommagées par la découverte du papier et du pinceau.* Klaproth, *Tableaux Historiques*, p. 35.

Babylonish records impressed on bricks

A yet more ancient downfal to literature by removing the means of spreading knowledge through printed signs, must have taken place at the destruction of Babylon. Mr. Hansard, quoting from Mr. Maurice's *Ruins of Babylon*, describes the substance used by the Chaldeans to preserve public records of whatever they desired to commemorate. A composition was prepared of clay mixed with reeds and formed into the shape of bricks. While yet in their moist state, the device or inscription intended to be published, was stamped upon them from some surface (probably of wood) with raised characters engraved on it for the purpose, and the stamped material was then subject to induration either by the Sun or by fire. The corroborative evidence of Mr. Hansard, a distinguished printer, (*Typographia*, p. 6.) is extremely valuable as to the mode of stamping that must have been used. Of this substance ἐξ ὀπτης πλίνθου of *burnt brick*, formed into square masses and impressed with mystic characters, the walls and palaces of Babylon were for the most part constructed. Three specimens are preserved in Trinity College, Cambridge, (one of them a cylindrical fragment covered with characters imprinted in longitudinal lines,) two or three in the British Museum, and several in the Library at the India House. The opinion of Pliny in his chapter of inventions, (*Nat. Hist.* lib. vii. cap. 56.) *Litteras* SEMPER *Assyrias fuisse*, bears a very striking reference to the Oriental origin of language, and of the arts of human intercourse by signs written, engraved, or printed.

Note (I.)

Origin of Block printing.

Papillon's opinion of Chinese Engraving.

Method of printing in China.

Specimens at the Library of the India House.

J'ai vu, says Papillon, whose authority as an honest witness is unimpeachable, *des livres Chinois chez M. Fourmont l'ainé, dont la gravure est admirable. Les liaisons des caractères sont si déliées et si nettes que nous aurions peine à les graver aussi proprement.* A great acknowledgment from the best xylographic artist of his day. *D'ailleurs la beauté de l'impression et la blancheur du papier sont si parfaites, que je n'ai encore vu ni lettres gravées ni aucune impression d'Europe qui mérite de leur être comparée. Tous ces livres sont imprimés foncièrement avec l'encre de la Chine, (car dans ce pays-là on n'use point l'encre à l'huile,) les feuillets ne sont imprimés que d'un côté, en sorte qu'ils sont pliés comme nos petits agenda de poche, et que chacun des dits feuillets sont doubles; cependant le papier est si mince qu'on a peine à s'en appercevoir.* V. *Traité de la Gravure en Bois*, tom. i. ch. vi. p. 59. He assigns also the thinness of the Chinese paper as the reason why it is never wetted. It is, indeed, too delicate and fragile a material for an ordinary printing-press; but from the circumstance of not being sized with alum, it has only to be brought into contact with the ink to take an immediate impression. The block (a not very thick tablet of pear, or apple-tree, or other hard wood) must first be firmly fixed in a horizontal position. Two brushes, one of a stiffer kind, (which may be held in the hand and used at either end,) the other softer and of an oblong form, must be provided. The stiff brush is dipped in the ink, and the block sufficiently rubbed with it to give an impression; but not so wetted as to blot and slur the characters. The block becomes gradually saturated, and in a state to print three or four sheets successively without a fresh supply of ink. But notwithstanding this advantage in saving time, it seems incredible that one man, according to Du Halde, can, without fatigue, print three thousand sheets a day. The softer brush is applied to rub the paper on the block with sufficient pressure to receive the impression. Du Halde, *Description de l'Empire de la Chine*, tom. ii. p. 299. Mr. Hansard, in his *Typographia*, 8vo. London, 1825, gives a most ingenious fac-simile of Chinese printing; it is executed after an original block, from which probably a mould was taken for casting it in type-metal. The original, which is five-sixths of an inch in thickness, being engraved on both sides, Mr. Hansard prefers to call a wooden leaf. This author mentions having seen in the Library at the India House, "several specimens in various stages of the process: some having the paper with the characters traced, ready glued to the board: some engraved but never printed from: others showing signs, like the original he has had copied, of much wear; and one very large block of a picture in outline. But all these are only engraved on one side and have a dove-tail at each end to slide into larger blocks, by which they are held firm for the workman's use. Several of their engraving and printing tools are also in the same Library, and confirm the account given of their workmanship." See CHINA, *Miscellaneous Division*, p. 589.

Note (K.)

The "marvels" of Marco Polo corroborated by other writers.

Polo's account of paper-money in China

The writings of Marco Polo, after his residence for eighteen years in China, resembled, in their reception among his contemporaries, the travels of Bruce, the celebrated explorer of Abyssinia. Marco Polo, says Mr. Ottley, preferred instructing his Countrymen in matters with which they were not hitherto acquainted, and relating wonders, which, until corroborated by other testimony, were not believed. His book for a long time was considered little better than a collection of fables of his own invention; later travellers, however, confirmed the truth of some of his accounts: but that which most of all established his veracity was the publication of *The Travels of the Two Arabs* in the IXth Century, who at that very remote period maintained and recorded their intercourse with the Chinese. A French translation of this Arabian author by Eusebius Renaudot, a learned Jesuit and Orientalist, appeared at Paris in 1718, 8vo. The writer of this narrative informs us, that all the *Chinese, both rich and poor, learned to read and write;* from which circumstance Mr. Ottley builds a very rational presumption that Printing was even then common in China. Manuscripts can never in any Country be a sufficiently cheap literature to be available for the poor, and least of all Chinese manuscripts. See Tiraboschi, *Storia della Letteratura Ital.* tom. iv. p. 103. and Ottley's *History of Engraving*, p. 50. 55. Marco Polo is not altogether silent upon Chinese Printing. He describes the process of stamping paper-money in the city of Cambalu, (Khâu-balek,) since called Pekin: to which process we have alluded in our biography of Confucius, p. 504. It is manufactured, says he, from the inner rind of the mulberry-tree made into a pulp, and reduced with size into the form of paper. It is quite black, and is cut, when finished, into large and small square or oblong pieces; according to the intended value. Public officers, deputed for the purpose, write first their names, and affix each one his mark; after which a principal commissioner, appointed by the Cham, *imbratta di cinaprio* (*cinabro*) *la bolla concessa gli, e l'impronta sopra la moneta, si che la forma della bolla tinta di cinaprio, vi rimane impressa.* (Smears with cinnabar the seal consigned to him, and imprints it upon the money, so that the figure of the seal coloured in cinnabar remains impressed upon it.) *Navigationi et Viaggi. Raccolto di* Ramusio, tom. ii. fol. 29.

German method of printing from wood similar to the Chinese method.

We have given, in the note immediately preceding this, a description of the Chinese process of Printing, compiled from Mendoza, the Jesuit Ambassador to China in 1584, by Du Halde. We now give from Breitkopf, (*Unsprung der Holzschneide kunst*, 2 theil, p. 160.) as quoted by Mr. Singer at p. 83 of his *History of Playing Cards*, a description of the method used in Germany by the early *Formschneider*, or Wood Engraver. "The artist," says M. Breitkopf, "planed a plank of pear-tree wood, and after neatly shaving and polishing it with a piece of sharp iron or glass either pasted an inverted copy of his design upon the wood, or if he were an adept in his Art rubbed off the pencilling of the original upon the plank. In the former case the drawing was entirely destroyed, since he must cut through it into the block; in the latter, the drawing was preserved, and it remained in his power to correct whatever was not distinctly expressed. He then with a small sharp instrument cut away the wood on each side of all the lines in the design before him, and leaving whatever space was marked with colour, chiselled the remaining wood away with other instruments. His labour thus completed, all the lines forming the object represented in the drawing would stand out in relievo. To make impressions of his work, he mixed lamp-black in water to the consistence of a paste; or used the common black ink, still sometimes employed by card-makers; poured some of the liquid upon a wooden trencher and filled a long-haired brush with it, which he passed over his wooden plank or block. In this manner he covered the prominent lines of his wood-cut with as much colour as was necessary for an impression. He next laid wet paper upon the coloured surface, passed over it a smooth broad piece of wood, or a thick horse-hair brush smoothed with oil, and continued this operation to and fro, until he perceived that all the lines of the wood plank were imprinted on the paper; which was then removed from the block, and his work finished." So numerous are the points of resemblance between this method and that practised by the Chinese that it seems obvious, almost to demonstration, that the Art of Engraving and Printing from wood was conveyed to Europe from China. See Palmer, *History of Printing*, p. 5.

Note (L.)

Discovery by Heineken of a wood-print dated A. D. 1423.

The earliest mention of the term *kartenmacher* (card-maker) in Germany, is found in the records of the city of Augsburg, which in the XVth Century, and some Centuries earlier, was one of the great depots of the Venetian merchants, through which, by land carriage, they furnished the Southern parts of Germany with articles of commerce and manufacture. Buxheim, at no great distance from Augsburg, is renowned in the annals of xylographic printing, for the discovery there, by Baron Heineken, of the earliest Print bearing a date of which at present any certain knowledge exists. It is the wood-print of Saint Christopher, dated 1423. It is preserved in the splendid Library of Earl Spencer in the same state as when Heineken discovered it, pasted in the inside of one of the covers of a Latin MS. of the year 1417: within the other cover of the same MS. is pasted likewise another wood-cut, "The Annunciation of the Virgin," but without a date. Both of them bear less resemblance to the angular stiffness of the German School than to the Italian style of Art, and though in both of them the explanatory Latin inscriptions are in the German or black character, yet that Gothic character, as observed by the Abbé Lanzi, (*Storia Pittorica*, tom. i. p. 72.) prevailed in Italy for inscriptions on Pictures till towards the close of the XVth Century. Neither of these Prints appears to have received the impression by the stroke of a soft brush on the back of the paper, according to the ancient method described by Breitkopf. Both, as Mr Ottley observes, are *printed with a press* upon a paper rather thick than otherwise, with black oil-colour, or what is commonly termed printing ink. It seems to us to combine the labours of an artist from Italy with those of a German pressman.

Note (M.)

Same kind of instrument, the roller, used in Europe as in China for printing from wood.

Mr. Savage, in his *Practical Hints on Decorative Printing*, observes truly of the roller used by Chinese artists, that it was one of the most ancient modes in Europe of taking impressions; and informs us that a hand-roller is sometimes used at this day by our Engravers on wood to obtain good proofs from their blocks. The simplicity of the method by a hand-roller would facilitate taking impressions in the private manner in which the Art, at first, was anonymously practised by European craftsmen. There would be no noise to excite curiosity, nor any cumbrous machinery to be concealed from the public gaze: of which Guttenburg, as we know, was extremely jealous. The probability is, that the hand-roller suggested the idea of the rolling press for taking impressions from metal plates.

First Prints from Wood.

An improved printing-ink.

On the subject of ink, Mr. Savage considers that the oil-colour, or printer's ink, used for impressions has frequently been injurious, and more especially to works printed in different shades or colours after the method called chiaroscuro. He looks upon the oil as not only producing changes in the colour used, but also stains in the paper, by separating itself from the colouring matter. He gives (at page 100 of his book above mentioned) a receipt for black printing-ink as follows:

	Ounces.
Balsam capivi	9
Best lamp-black...........	3
Prussian blue	1½
Indian red.................	¾
Turpentine soap dried	3

"ground on a marble or stone slab with a muller to an impalpable fineness." Instead of the lamp-black, Prussian blue, and Indian red, other colours may be tried, and impressions obtained of coloured works in chiaroscuro, which, Mr. Savage maintains, will not exhibit the defects of common printing-ink.

German ink excellent, at the first appearance of this Art.

Ink appears an ancient Roman invention, a *paint*. (See Ink, in the *Miscellaneous Division*.) Mr. Ottley observes, that a proper black ink for printing made its appearance in Germany simultaneously with the introduction of the Press; and the first Bible that issued from the Press of Guttenburg at Mentz, soon after 1450, is printed with ink, which in blackness and consistency has never been surpassed. *History of Engraving*, p. 92. Mr. O. appears to infer that the Italian style of the Buxheim Prints of 1423, mentioned in a former note, which are printed with black printing and in a press, might claim for the Press also a Venetian origin.

Note (N.)

The date of this dedication must, of course, be limited to the period during which Honorius IV. held the Papal chair: namely, between April 2, 1285, when he was elected, to April 3, 1287, when he died. The Baron Heineken joined the Parisian dilettanti of his time in endeavouring to laugh to scorn Papillon's sentimental story of the Cunio: but Heineken, though he bears testimony to the upright character of Papillon, and expresses his confidence that he did not invent the story, is himself severely observed upon by De Murr, as guilty of palpable misrepresentation. *Je ne sçai pas pourquoi M. de Heineken cite si faussement ce trait si curieux et remarquable*, (alluding to Papillon's narrative.) *Au lieu d'Honore il mit Urbain. Il dit que M. Papillon étoit alors* 14 *ans, mais il en avoit au moins* 21, *étant né l'an* 1698. Murr, *Bibliothèque de Peinture*, &c., 12mo. Frankfort, 1770. Heineken likewise asserts that no Count Alberico Cunio existed in the time of Pope Honorius IV.: but the Abbé Zani (*Materials*, &c. p. 233.) quotes Tonduzzi's *History of Faenza*, printed in 1675, which records, from A. D. 1149 to A. D. 1285 inclusive, many interesting particulars of the Cunio family, and of successive Counts, Guido, Bernardino, and Alberico. The character, too, we must here add, of Honorius IV. was that of a cultivator of Literature, and peculiarly favourable to the tasteful pursuits of his young relatives. He is thus described in vol. i. p. 306, of *L'Art de vérifier les Dates*, fol. Paris, 1783: *Honorius IV. aimoit les lettres, et projetta, pour les faire revivre, des établissements que la brièveté de son Pontificat, et les conjonctures où il se trouva, ne lui permirent point d'exécuter.*

The Abbé Zani's inquiry respecting the Cunio.

Further particulars.

The following is the translation given by Mr. Ottley (*Hist. of Engraving*, p. 13.) of Papillon's French version of the dedicatory inscription at the beginning of the Work. "The heroic actions, represented in figures, of the great and magnanimous Macedonian King, the bold and valiant Alexander; dedicated, presented, and humbly offered to the most holy Father Pope Honorius IV., the glory and support of the Church, and to our illustrious and generous father and mother, by us Alessandro Alberico Cunio and Isabella Cunio, twin brother and sister: first reduced, imagined, and attempted to be executed in relief, with a small knife, on blocks of wood, made even and polished by this learned and dear sister; continued and finished by us together, at Ravenna, from the eight Pictures of our invention, painted six times larger than here represented; engraved, explained by verses, and thus marked upon the paper, to perpetuate the number of them, and to enable us to present them to our relations and friends in testimony of gratitude, friendship, and affection. All this was done and finished by us when only sixteen years of age." The original inscription is state by Papillon to have been in Latin or ancient Gothic-Italian : an internal evidence of which fact is, as Mr. Ottley observes, the cramped style of Papillon's, or rather M. Greder's, French translation. It proves itself to have been "done into French" *bonâ fide*, and literally, from a Latin original. (V. Papillon, *Traité de la Gravure en Bois*, tom i. p. 84.) Mr. O. also remarks, that although the scholarship of Papillon might be insufficient for deciphering this ancient dedication without assistance, he must at least have been able to make out the proper names, Alexander, Pope Honorius IV. and those of the two Cunios. Then as to his competency on artistic points, it cannot be disputed. He mentions a memorandum, written probably by one of the Cunios, (for the copy in question was preserved in their family,) on the margin beneath one of the Prints to this effect : "*The ground of the wooden blocks must be hollowed deeper, that the paper may not touch it any more, so as to be smeared, in receiving the impression.*" He says the blocks appear to have been printed by means of the pressure or friction of the hand, with a light tint of indigo in distemper, and describes the impressions to be granulous, as if the paper had been applied to the engraved block without being first damped. This is, says Mr. O., exactly a circumstance usual with very early wood-prints. They were printed without any mixture of oil in the colour used for the purpose : and there is good reason to presume, from the shining appearance of the backs of old Wood Engravings of this kind taken off by friction, that the paper was commonly used dry. Wet paper would not have withstood the friction which appears to have been applied.

The fate of these amiable twins was untimely : the youth, trained to war, (a chief employment of Italian gentlemen in those days,) followed his father, the Count Cunio, in one of the expeditions which then so frequently embroiled the petty States of Italy. It was after signalizing himself so as to be knighted in the field, for his courage and conduct, and during the subsequent interval of his being ordered to Ravenna for the cure of his wounds, that he began to compose and engrave with his sister the Work in question. They continued afterwards to employ together the few seasons of respite from Civil warfare in this peaceful occupation : but in a fourth campaign with his father, the brave young cavalier fell covered with wounds, and the affectionate Isabella, broken-hearted by his loss, died not long after. It is to be regretted that Papillon lost sight of this curious Work upon the death of his Swiss acquaintance. The Library of the Vatican is said to have been searched, but hitherto in vain, for a supposed presentation copy to Pope Honorius IV.

Zani, in the passage of his Work above alluded to, observes of the notices which he was so fortunate as to collect from Tonducci's *History of Faenza*, that although no mention is expressly made respecting the two twins of the family of Cunio, nevertheless there is great probability that a Count Alberico Cunio (spoken of as a celebrated character in the same year when Honorius IV. was elected Pope) was the father of Alessandro Alberico and Isabella.

Note (O.)

acred
yptics.

The first-mentioned of these compound or mixed modes of blockwork was one of the earliest, and was practised by the *kartenmacher*, and by the manufacturers of movable altar-pieces called *ancone* by the Italians. The word is conjectured to be a corruption from *εἰκὼν*, *icon*, an image. Jansen adopts the opinion of Breitkopf, that the *kartenmacher* were subsequent to the illuminists. Throughout ancient Christendom the use of these sacred dyptics was very general. The oldest Print extant with a date, called the Buxheim Print, of which we have already spoken, (see note (L.) above,) was coloured in this manner, as likewise its companion, "The Annunciation." Both, it is probable, were originally designed to fold up in a portable form facing each other, to be opened on occasions of devotion, and when the Mass was to be celebrated. Probably many more of these (not treasures of Art, but rather) biblical relics remain yet undiscovered in the Religious Houses of Germany. Excellent fac-similes of the two Buxheim Prints, and of another considered still older, representing St. Bridget, are given in Mr. Ottley's *History of Engraving*. The colouring, or tinting, however, is purposely omitted, in order to show with more distinctness the lines of the Engraving. The colouring of the original St. Bridget is not laid on by means of stencils, but by the hand. (*History of Engraving*, p. 88. note.) Both the original St. Christopher and the "Annunciation" are stencilled, and both with the same colours, and both appear to have been printed on the same paper. (p. 91.)

heir uses.

Lanzi describes the uses to which these sacred Pictures, dyptics, or movable altar-pieces (*che in più paesi d'Italia si nominavano ancone*) were applied, and thus quotes from Buonarotti : *Uso antichissimo de Cristianesimo fu tenere sopra gli altari nel sacrificio della messa i dittici d'argento o di avorio, che, finita la sacra funzione si ripiegavano, come un libro, e si recavano altrove. Ritennesi la stessa figura anche introdotte le tavole più grandi, che similmente erano due ed amovibili ; e questa usanza di cui poche reliquie ho vedute in Italia, si è conservata lungamente nella chiesa Greca. Finalmente a poco a poco si cominciò a dipingere in una sola tavola unita.* (V. *Storia Pittorica*, vol. i. p. 72. note.) The ancone are particularly specified in the Venetian decree of 1441. (See fourth note to Art. 25.)

Wood-cuts.

Note (P.)

Progress of Engraving in chiaroscuro.

The phrase printing in *chiaroscuro*, or in cameo, has been exclusively applied to this compound process of Engraving, although it must be evident that all engraved works, except mere outlines, imply the knowledge and practice of chiaroscuro. "It is supposed that at first only two blocks were used ; one to give the outline and the shaded parts, and the other the coloured ground out of which the lights were cut, to imitate their being put in with white ; and this effect was produced by impressions on white paper. In a very few years the process was carried further, so as to imitate drawings in chiaroscuro, and with such success as to induce some of the greatest artists to encourage it by their assistance in drawing the subjects on the blocks. These early productions were confined to three or four blocks printed with different gradations of shade of the same colour which produced the effect of what is termed chiaroscuro. Their general colours were dull ochry yellow or brown ; sometimes they used a grey ink ; sometimes a reddish colour ; sometimes dull blue or purple ; and they occasionally varied the colour of one block ; so that we meet with the same subject printed in a variety of ways, and producing different effects. In many instances they did not engrave an outline, but produced their imitation of drawing by gradations of tints, the termination of the tint being the termination of the subject ; while different depths produced the draperies and shaded parts." (Savage, *Practical Hints.*) The same distinction is made by Bartsch, (*Anleitung, &c.* th. 1. sec. 118—120.) between 1. the process by means of two blocks for imitating drawings on coloured paper touched up with white ; and 2. the imitation of drawings in bistre or such as contain, three, four, or even five tints laid on in flat masses. To this second style, requiring at least three and frequently four separate blocks, he gives the name *grau in grau*, (grey upon grey,) or *camayeux*, because intended to imitate Paintings known by that name. For a further account of these processes, see Papillon, *Traité de la Gravure en Bois*, tom. i. ch. ii. iii. and iv. To these methods Mr. Savage adds, in the Work just quoted, a further attempt in which he has succeeded but indifferently to imitate coloured drawings. He introduces various specimens from Paintings and Drawings by Callcott, Neale, Craig, Varley, and Brooke, some in a suite of seven blocks, one of thirteen, one of fourteen, and one (a sad failure !) of no less than twenty-nine blocks.

Note (Q.)

Card-makers the earliest xylographers.

The card-makers, according to Adam Bartsch, were the original cutters in wood, (*formschneider*,) but probably only became a distinct Corporate Body in Germany after they had laid aside the manufacture of cards, and were solely employed in engraving Pictures. This epoch, however, is not ascertained. We only know that they assumed the name of *formschneider* about A. D. 1449. In proportion as printing-offices in the XVth Century became more numerous, and the demand for books increased, (which, in imitation of the MSS. of that period were crowded with Prints and pictorial illustrations,) the number of craftsmen in this profession multiplied ; and, as happens with a multitude of professors in any Art or Science, divided their labours, each taking a peculiar department. Hence arose numerous distinct branches, more particularly in Nuremburg and Augsburg, between the years 1459 and 1486. But the *formschneiders* separated themselves into a higher class as soon as their connection with the profession of Painting raised their Art beyond a mere mechanical trade.

It has been a question whence the grotesque figures on modern court cards could have been derived. They bear no distant resemblance to some of the representations of the human figure among the Chinese, and it will be seen that their modern cards are charged with similar designs, but we have no certain clue to guide us in ascertaining whether ours were thence derived. (V. ENGRAVING, pl. i.) The figures in Mexican hieroglyphic Paintings also afford objects very resemblant to those on our court cards, but there is not any reason for supposing that with them they have any connection. Perhaps we ought to seek no further than the rude cuts of the XIVth and XVth Centuries, many of which are as remote from being correct imitations of humanity, as are the similar objects depicted on the figured cards of the present time. Singer's *Hist.*

of Playing Cards, 4to. p. 215. Heineken proves the manufacture of playing cards in Germany to have existed as early as A. D. 1376.

Bartsch gives a long list of the different divisions of labour resulting from the increased quantity of work, and the consequently increased number of workmen. He mentions the *kartenmacher*, (card-makers,) *kartenmahler*, (card-painters,) *briefmahler*, (letter-painters,) *briefdrucker*, (letter-printers,) *formschneider*, (block-cutters,) *modelschneider*, (model carvers,) *modisten*, (modellers,) *patronisten*, (stencil or pattern-makers,) *schachtelmahler*, (box-painters,) *illuministen*, (illuminists,) and *schönmahler*, (gilders.) He then proceeds to a brief history of each department. The old letter-painters and pattern-makers still continued their occupation, and have existed to the present day through various stages of improvement. The model carvers went over to the manufactories of printed cottons and linens; and the *illuministen* and *schönmaler* to the Engravers on copper, in whose service they are still partly engaged. But the block-cutters, or *formschneider*, separated themselves entirely into a distinct Body, continuing gradually to improve their Art, as it more and more became connected with Painting and Design. *Anleitung, &c.* th. i. sec. 594.

Note (R.)

Biblia Pauperum.

To instruct those who could not afford MS. copies of the Scriptures or of religious books, which were sometimes expensively and magnificently illuminated, and which, even when cheapest, were too costly for the common people, a small folio, entitled *Historiæ veteris et Novi Testamenti seu Biblia Pauperum*, was published. Copies of it have long been among the literary rarities of our times. The *Bibliotheca Spenceriana* of Dr. Dibdin may be referred to as peculiarly rich in treasures of this kind. Mr. Ottley, whose *History of Engraving* contains much curious matter concerning the *Biblia Pauperum*, describes it as a small folio of forty leaves, printed on one side of the paper only, by means of friction, from the same number of blocks of wood, or, more probably, from twenty blocks, in which case each block would contain two engraved pages. The blank sides of the paper were then pasted together, so as out of every two to form one leaf, with the appearance of being printed on both sides: in which respect, observes Mr. O., as well as in its brown tint, apparently unmixed with oil, it resembles most of the early block books. (p. 112.) Each Print or page being from 9¼ inches to 10½ inches in height, by about 7¼ inches in breadth, furnishes three subjects from Scripture history, disposed in compartments side by side, across the middle of the page. The space above the central subject is occupied by two half-length figures of prophets, patriarchs, or holy men. The space below is similarly occupied, and the remainder of the page at its four corners is taken up by rhythmical and other inscriptions in Latin, explanatory of the events and persons represented. These pictorial representations are coloured in a rude manner, unworthy, in many instances, of the Engraving. The Work passed through several editions, which Heineken is very careful to particularize, as did also the *Vision of St. John*, published in a similar manner about the same time. This *Biblia Pauperum*, or Poor Man's Bible, excited in those days no peculiar interest beyond its being thought a cheap compendium of religious knowledge. Modern estimation, however, entitles it to the name of *Biblia divitum*. Mr. Hansard (at p. 36 of his *Typographia*) thus states the prices that have been given in the XVIIIth and XIXth Centuries for the *Poor* Man's Bible of the XVth:

		£.	s.	d.
1753 at the sale of	M. de Boze, 1000 livres,	43	15	0
1769	M. Gaignat, 830 livres,	36	6	0
1791	M. Paris	51	0	0
1813	M. Willett	257	0	0
1818 or 1819....	Duke of Marlborough ..	52	10	0

Note (S.)

A. D. 1456. Invention of fusil types.

That great step (says Mr. Hansard, quoting from Horne's *Introduction to Bibliography*) towards perfecting the Art of Printing, namely, the invention of fusil types, appears pretty well ascertained to have been in the year 1456. Twenty-five of the leaves of the *Speculum Humanæ Salvationis* were printed before that invention; and the remaining thirty-eight leaves, together with the Preface to complete the book, had the advantage of cast type. The second Latin edition differs from the former, in having the whole of the explanatory text printed with fusil type, exactly resembling those employed for part of the letter-press of the first edition. In the Flemish or Dutch editions, the text is printed entirely with movable type.

The chronological order in which the discoveries in Typography succeeded each other, has been put down thus:

Printing from blocks, about A.D...	1422
Letters cut separately of wood....	1438
Do. do. of metal....	1450
Do. cast in moulds..............	1456

So that little more than thirty years elapsed from the state of the Art at the time of printing the *Biblia Pauperum*, to the time of casting the first metallic type from the *foundery* of Gutenburg and Schoeffer.

Mr. Ottley maintains that of all the block-work so elaborately described by Heineken, only three, *viz.* the *Biblia Pauperum*, the *Canticles, or Hist. Virginis Mariæ*, and the *Speculum Humanæ Salvationis*, can claim any distinction as works of Art; and on this account considers these three as rather appertaining to the ancient Schools of Holland and Flanders, than to that of Germany.

Note (T.)

Invention of early Works involved in mystery and kept secret.

The mysterious concealment which attended the early performances in the Art of Printing, as well from blocks as from types, has left almost every thing to antiquarian surmise, especially respecting the original projectors. Inventors seldom foresee the utmost value of their εὕρημα. Their only aim at first is to do something better or cheaper than what they see already done. The first object in printing figures of Saints, &c. was to imitate Drawings, as the first in printing books was to imitate MSS., and the care and accuracy necessary for this latter process accounts for the excellence of early Printing. Such, observes M. Beckmann, is the usual progress of inventions. After the invention of Printing, people endeavoured to make printed books as like as possible to manuscripts, because they imagined that this invention was to be approved only so far as it enabled them to imitate these, without observing that it could far excel the Art of writing. So when artists wished to make mirrors of glass, they would try to imitate the only mirrors known: those, namely, of natural glass or vitreous stones. *History of Inventions*, vol. iii. p. 183. We conceive it also probable that the number of persons who obtained a comfortable subsistence by transcribing and copying and illuminating must have looked with so much jealousy upon this new craft, as often to make obscurity and secrecy essential to the safety of the craftsman.

M. Bartsch seems to think that the names of those who engraved such Works as we have just alluded to, *viz.* the *Biblia Pauperum*, deserve oblivion. He deems them to have displayed in these mere outlines such total absence of Art and ignorance of design, as to be unworthy of mention as artists; and even estimates them below the most insignificant cutter of models for cotton-printing. *Anleitung, &c.* vol. i. sec. 598. Our Countryman, Mr. Ottley, has made a different estimate; and has been at the pains, in his valuable Work, to give several fac-similes, of which he speaks highly as compositions, as possessing agreeable and graceful design, admirable draperies, sober dignity of style, and often a considerable share of grandeur. *Hist. of Engraving*, p. 111—171. We so far agree with M. Bartsch, however, as to regard the very early performers in wood (whether Italian or German) in the light of only a very dexterous description of mechanics employed to work upon and carve out a design already traced for them by a superior hand. Hence the name of the designer only has been sometimes transmitted, and mention very rarely made of the Engraver. The examples are numerous at the beginning of the XVth Century from the Presses of Mentz, Strasburg, and Haerlem. In Bartsch's *Peintre Graveur* will be found a multitude of names and monograms, which that author has rescued from the hiding-places to which antiquity had consigned them.

Great dexterity shewn in ancient xylography.

But, at the same time, we cannot imagine that any designer, conscious of superior skill, and jealous of his reputation, would intrust his labours so entirely to this executioner, as never to concern himself further. On the contrary, it may have frequently happened, that the employer was a far better workman than his *employé*, and it would always happen that the genius and inventive powers of the master-mind would be incessantly active in endeavours, by improving the *méchanique* of the Art, to give his printed works the best pictorial effect possible. And, indeed, so apparently difficult of execution are the cross-hatchings in several ancient specimens, that many authors, writers on Engraving, and themselves Engravers, have expressed a belief that the work was not performed by manual labour and care only, but must have been assisted by some unknown process. The cheapness of labour, however, in the days of Albert Durer makes this latter hypothesis unnecessary: besides that many admirable xylographic works in our own time prove the practicability of the manual process, which to an Engraver only on copper might seem next to impossible.

Note (U.)

In the *Peintre Graveur*, vol. vii. p. 245. Strutt's opinion (who

H. Schaeufflein.

follows Heineken) respecting two of this name, a senior and a junior Schaeufflein, is treated as merely conjecture. A mark of Schaeufflein was two baker's peels crossed. *Schaeufel* means in German a peel, *Schaeufelin* a little peel.

H. Aldegrever.
W. Resch.
J. Binck.
N. Meldemann.
H. Guldemund.
S. Hamer.

Several other Wood Engravers and designers connected with Nuremberg have their works both on wood and copper particularized in the *Peintre Graveur; e. g.* of *Henry Aldegrever*, (vol. viii. p. 455.) the pupil of Durer, are mentioned one wood-cut and 289 copper-plates one of them etched; (vol. viii. p. 362.) of *Wolfgang Resch*, (vol. vii. p. 473.) who designates himself *Formschneider*, one specimen in wood; of *Erhard Schoen*, (*Ib.* p. 476—481.) painter, at Nuremberg, who died about 1550, 40 cuts; of *James Binck* (vol. viii. 249.) one wood-cut and 97 copper-plates, one of them *à l'eau forte sur fer.* To these add *Nicholas Meldemann* (vol. vii. p. 482.) and *Hans Guldemund*, (ix. 150.) both of them card-makers or card-sellers (*cartiers*) of Nuremberg, and *Stephen Hamer*, (*Ib.* p. 151.)

Causes of inequality in Wood Engravings with the same monogram.

Of the cuts in a Poetical Work under the title of *Tewrdanck*, fol. Nuremburg, 1517, reprinted 1519, Bartsch observes, *Ces estampes, au nombre de* 118, *ne sont pas d'une perfection égale. La différence qui se manifeste dans leur exécution, prouve qu'elles ont été faites par différens graveurs. Cependant il est certain qu'elles ont été toutes gravées d'après les desseins de Hans Schaufelein qui a marqué huit pièces de son chiffre: qui surpassent pour la fermeté du dessein toutes les autres; il est à croire que Schaufelein lui-même en a tracé le dessein sur les planches.* (*Ib.* vol. vii. p. 272.) In another passage the same author enumerates various causes for the great inequality of merit to be found in wood-cuts bearing the same cipher. Some of them, says he, are very fine, because the designer has himself drawn his own composition on the block, and the Engraver has had only the labour of cutting away with proper accuracy the intervals between the lines and hatchings of the design. Other prints, again, are of an inferior kind, because the Engraver has been only guided by a counter-drawing, (Painting, last note to Art. 216.) where the lines, after tracing, lose a portion of their originality and spirit. Others, likewise, are faulty, because the Engraver spoils the effect of some fine picture by working after an ill-drawn copy, of perhaps his own doing. Other prints, too, with even the advantage of good original composition, are sometimes but lamely executed, because only executed after slight sketches in bistre, to which the hand of a mere mechanicial Xylographer has been incapable of supplying the occasional imperfections of contour, together with the appropriate hatchings for parts shaded by a wash of colour, or by a stump. Lastly, a piece may be engraved with perfect neatness by an artist well practised in the use of his tools, and yet be quite defective in drawing; or, on the other hand, it may be admirably drawn, but executed in coarse and laboured endeavours by an unskilful hand. V. *Peintre Graveur*, vol. vii. p. 26.

Note (V.)

Opinion of Mr. Ottley respecting Xylographic monograms.

For our further account of Holbein, see Painting, at p. 485. Mr. Ottley remarks upon the statement of Bartsch, quoted in the foregoing note, that a large proportion of the wood-cuts bearing the monograms or initials of Durer, and other eminent designers, may be fairly considered as engraven upon the wooden blocks by other hands; but, continues he, I can by no means persuade myself that the abilities of the ordinary Wood Engravers, who abounded in Germany at the close of the XVth Century, could have been such as to render them in any material degree instrumental in bringing about that sudden and almost miraculous improvement which took place in their Art at that period. They were uninstructed in the rudiments of design, and had been accustomed from their infancy to manufacture the barbarous wood-cuts used by the illuminists and venders of cards and devotional images, in which scrupulous exactness in the copyist would have been a mere waste of time; they must have been utterly incapable of comprehending or appreciating those delicate, but free and masterly touches which characterise the designs of a great and finished artist like Durer; and of consequence wholly unqualified to represent them upon the wooden blocks with any tolerable degree of fidelity. We may, indeed, suppose them to have handled the tools then used in their Art with that dexterity and ease which long practice ensures; but that is all; and it is probable that these tools were few in number, and but ill adapted to the complicated and delicate kind of workmanship that was required in Wood Engravings of so much more finished a character than those which they had hitherto been called upon to execute. I therefore consider it as certain that the numerous and flourishing School of Wood Engravers which we find spreading over Germany, and from thence to Italy, in the early part of the XVIth Century, owes its excellence to the great designers of that time; and especially to Albert Durer, who, I have no doubt, assiduously applied himself in his youth to the practice and improvement of the Art; and, afterwards, perceiving the advantages likely to be derived from it, taught it to numerous pupils, who, already grounded in the principles of design, and working constantly under his own eye, by degrees became qualified to assist him greatly in his numerous works of this kind, and, at length, perhaps, competent to the task of engraving the designs of their master even without his superintendence. My opinion is not a little strengthened by the circumstance of Durer having been himself the publisher of all his chief works of this kind; added to the fact, that of the years 1509, 1510, and 1511, in which so large a portion of his Wood Engravings were executed, we have scarcely anything by his hand engraved on copper. What has here been said of Durer will, I think, be found more or less applicable to other great artists of the German School, his contemporaries or successors, of whom we have numerous wood-cuts; and especially to Holbein, whose admirable designs, engraved with incredible delicacy on wood, adorn so many of the books printed at Basle and some other places, between the years 1520 and 1540. Among the productions of Holbein in this way is the justly celebrated series of the Dance of Death, of which the edition commonly thought to be the first was printed at Lyons, 1538, in small 4to., under the title of *Les Simulachres et Histori des Faces de la Mort:* the cuts are forty-one in number. Each cut is surrounded by a Latin text, taken from Scripture, and has underneath it four French verses. Mr. Ottley then goes on to show that the artist employed under the direction of Holbein to engrave most of these his designs in wood, and who, as appears from the first dedication of the work, died before their completion, was named (according to Jansen, *Essai sur la Gravure*, tom. i. p. 120.) Hans Lutzelberger. Eight additional pieces appeared in the edition of 1547, seven years before the death of Holbein. The original drawings for these eight, together with those for thirty-eight of the prints in the first edition, were in the possession of Jan Brockhorst, the painter, a contemporary of Vandyke. These drawings (executed with a pen) found their way, forty-six in all, into the cabinet of M. Crozat, and were disposed of at the sale of his collection. They were lent to Mechel, of Basle, who published Engravings from them in 1780. They are now said to be in the cabinet of the Emperor of Russia.

Holbein's "Dance of Death."

Note (W.)

Family of Mair.

Strutt particularizes a singular chiaroscuro print, by the elder Mair, of the Virgin and Child, with Joseph holding a candle, and the date 1499. Respecting the later artist of this name, he regrets that he did not exercise his talent on any better subject than vignettes for books. Bartsch, in vol. ix. p. 597. of his *Peintre Graveur*, mentions Alexandre Mayer, but not as a Wood Engraver. Strutt, however, styles him such, as also a Paul Mair, supposed to be of the same family, but born at Nuremberg.

Schnitzer.
L. Kranach.
Urse Graf
H. Brosamer.
H. B. Grün.

We might here introduce some others of the ancient School. *Johan Schnitzer*, of Arnsheim, engraved maps for the edition of Ptolemy, published at Ulm in 1486. *Lucas Kranach* is recorded by Bartsch (*Peintre Graveur*, vol. vii. p. 279.) as the author of 154 subjects in simple Xylography, the earliest dated 1505, the latest 1561. Six copper-plates, five of them portraits, are likewise ascribed to him. Of *Urse Graf*, who flourished at Basle in 1508, he records 17 pieces, (*Ib.* 456.) and but one copper-plate. Of *Hans Brosamer*, a painter, who lived at Fulda between 1537 and 1550, he describes 15 Xylographic pieces, and 24 copper-plates. (vol. viii. p. 455.) To *Hans Baldung Grün* he assigns (vol. vii. p. 305.) a selection of fifty-eight subjects. Baldung was also a painter in the style of Albert Durer, his contemporary; his drawing is not very correct, but there is fine expression in his heads. *Le chiffre composé d'un G au milieu d'un H et d'un B attaché au dernier jambage est expliqué par quelques auteurs* Hans Bresang, *par d'autres* Hans Grunewald; *et par d'autres encore* Hans Baldung Grun. *Il n'est pas vraisemblable que trois artistes qui vivoient dans un même temps se soient désignés par un même monogramme. Peintre Graveur*, vol. vii. p. 301. Bartsch then goes on to prove that his *nom de famille* was not Bresang nor Grunewald, but Grün. His ordinary appellation, however, appears to have been Hans Baldung. He is said to have engraved on wood only; two copper-plates, however, are ascribed to him. (*Ibid.*)

Altdorfer.

Albert Altdorfer, of Altdorf, (in Bavaria,) is among the reputed scholars of Durer; of his wooden cuts it is remarked, by Strutt, that Hans Holbein must have derived great assistance from them, since evident traces of Altdorfer's style appear in Holbein. Bartsch ascribes to Altdorfer sixty-three pieces in wood. He became a Senator of Ratisbon, where his family had been established; was appointed architect of that city, was highly respected, and died there, A. D. 1538. His copper-plates amount, according to the same authority, to 96 pieces, 13 of them *à l'eau forte*. *Melchior Lorich*, or Lorch, born A. D. 1527, at Fleusburg, in Holstein, a Painter, Engraver, and Antiquary, is noted by Bartsch as the author of four works in wood, the last of which comprises a series of 127 cuts. The same author describes 16 copper-plates by Lorich, one of them etched, (*Peintre Graveur*, vol. ix. p. 500.) We may here subjoin the name of a supposed German artist, *Wendel Reich*, a Wood Engraver who lived and worked at Lyons, A. D. 1515. *Crispin Vanden Broeck*, a Flemish painter, born at Antwerp about 1530, engraved creditably both on wood and copper from his own designs.

Note (X.)

A "Knight-errant mounted and in complete armour, with his attendant by his side on foot," is the last of the ten described by Bartsch. The print is highly praised by Papillon, (tom. i. p. 387.) who ascribes it to some early German artist unknown to him.

The ninth volume of the *Peintre Graveur* mentions (at p. 407.) a specimen *de trois planches* on the subject of "Absalom slain by Joab," by an unknown master, whose style is thought to resemble that of Martin Van Veen, called *Martin Hemskirk*, from the place, near Haerlem, where that painter was born in 1498. The same volume, at p. 426, records a chiaroscuro by *George Matheus*, whose name appears in white characters upon the print thus, "Jorg Matheis, Furmschneider" (*here a word is imperfect*) "Augspurg." The execution is commended as extremely good, and the style as resembling the Italian School. Various other artists in chiaroscuro are enumerated by Papillon, but it seems doubtful whether they were the Engravers or only the designers.

Bryan (*Dictionary of Painters and Engravers*, 4to. 1816) ascribes a chiaroscuro, "The Kings of Israel," to *Lucas von Leyden;* and three cuts in chiaroscuro to *Lucas Cranach*, but does not give his authority, (probably Heineken.) This latter artist is hinted at under the name Lucas Cranis by Papillon, (tom. i. p. 392.) who mentions a chiaroscuro in his possession, dated 1508, with the mark of Hans Burghmair. *Cette estampe*, says he, *n'a que deux planches ainsi que les premiers camaieux*. (tom. ii. p. 390. see also Bartsch, *Peintre Graveur*, vol. vii. p. 198.) Papillon adds afterwards the names of several others. (*Ibid.* p. 400—407, and the whole of the following ch. iv.)

Note (Y.)

Papillon's instrument.

His principal implement seems to have been a kind of knife, the blade of which he describes to be about four or five inches long, formed of the same material as the springs for watches, and duly tempered. This blade was separable from the haft, and inserted through a longitudinal groove or slit, along the middle of a cylindrical wooden handle, of the same thickness as the breadth of the blade. The end of this handle, where the slit admitted the blade, was bevelled off on three sides, round which were cut several notches, for securing the blade firmly with a strong waxed thread. The remaining side of the handle was kept level with the edge of the instrument. The part of the blade intended for use was made to protrude about an inch and a half beyond the handle, and to be sharpened and pointed somewhat like a common penknife. When this part was worn away by use or broken by accident, the waxed cord that had been wound along the entire handle was loosened, and the blade drawn out to the same length as before, to be again sharpened, and again tied and adjusted for making incision on the wood. For cutting out any part two incisions at least must be made. The first of them Papillon calls *la coupe*, the second *la recoupe*. The former follows the direction of the line: the latter in the same direction cuts out a slice entirely from the block. And as two such slices must invariably be cut away on each side of every line in the work of the Wood Engraver, a great difference is manifest between his labour and that of the Engraver on copper. To produce a line which an Engraver performs on copper-plate at one stroke of his burin, requires on wood no less than four separate incisions. And the patience of the Xylographer is yet more put to the proof when he endeavours after cross hatching, which in Xylography has seldom, for ordinary purposes, been extended beyond two courses of lines.

Less time, however, is required for executing several courses in cross hatching than for a smaller number. In some instances (such as in many of the works of Thurston, mentioned in our last note to Art. 31.) every line of the hatchings has been first drawn by the designer with a pen or pencil on the block, and no more remains for the Engraver than the process (a process certainly that requires the utmost accuracy) of picking away those parts which must come out white in printing; namely, all the parts between the lines. The greater, therefore, has been the multitude of crossings, the greater will be the portion of surface to be left black, and the fewer interstices he will be required to pick out.

Instruments for Engraving.

Concerning some of the instruments for simple Chalcography, such as the *burin*, and the *dry point*, and the *scraper*, some account has been already given. (See second note to Art. 19, and Note B.) In Chalcography, as in Wood-Engraving, the form and thickness of the graver must be suited to the kind of line to be drawn. It has been the practice to support the copper-plate, during the work, upon a round cushion, or leather bag filled with fine sand, and varying in size according to the dimensions of the copper, so as to be generally about nine inches in diameter and three in thickness. Resting upon this sandbag the plate of copper or steel is held in the left hand, and either kept steady, as in cutting straight lines, or turned about in a direction to meet the course of the graver, as in forming curves. The Abbé Longhi invented a movable table, (pl. i. fig. 8.) in which the copper-plate A is attached to a movable board B by screws. The board that supports the plate may readily be inclined at any given angle by means of the resting table C and support D. Immediately beneath A is placed a strong iron axis, on which the plate is also made to revolve: and in order to diminish the friction which would otherwise arise from the weight of a large plate the board is supported by friction rollers. A number of holes may be made in the board, to receive, alternately, the iron axis; so that the centres are readily changed for the various lines that may be required.

Abbé Longhi's invention.

Execution of broad strokes on copper-plate.

Very broad strokes should be made of several lines very close together, and cut till they are a little below the general surface of the copper. By this means, the bottom or channel of a broad stroke is sufficiently rough to retain the ink, and not so deep as to overload the paper with it. As depth of lines depends upon the degree of pressure from the hand, so clearness of lines depends upon the habit of producing them at one cut. Observe, in using the scraper (Note B.) for removing faults in the work, to incline its edge to the copper, so as to scrape it evenly, and that no false strokes or scratches may be left upon it. For removing these, another instrument is necessary, called a *burnisher*. (See pl. i.) When rubbed upon the copper, it clears away all roughnesses, polishes the surface, takes out such lesser defects as do not require the scraper, and reduces such lines as have been cut too deeply. Another implement is the oil rubber, (*Ib.*) consisting of a roll of felt or linen cloth dipped in olive oil, which, tinged with a little lamp-black, sinks into the strokes, and gives them a blackish appearance, that the artist may from time to time form a judgment of his work. The oil rubber, however, must be used gently, and as seldom as convenient, since whatever takes off the sharpness from the edges of the engraved lines diminishes the sharpness of the impression. An *anvil* or *punch* (*Ib.*) is also occasionally wanted to place the plate upon in hammering out the hollow parts or erasures made by the scraper. When the surface is made as level as the hammer can make it, the burnisher is next applied, and the whole polished with a piece of good charcoal. The burin is sharpened from time to time in the same manner as a chisel, by rubbing the lozenge or bevelled surface on a proper oil stone, which must be made of the best Turkey hone. The temper of the steel is generally too hard in a new burin just bought, but improves and softens after a little grinding and whetting. A *screen*, formed of tissue paper pasted upon a slight frame, is generally placed in a sloping direction before the window at which the artist sits, to keep off the glare of light, which, falling otherwise upon the metal surface, prevents him from seeing properly his work. In order, too, that his print may come out creditably from the press in the spirit of its original, every line must be represented in reverse with perfect exactness. He places, for this purpose, the original opposite to a *mirror*, so that he can see the reversed picture, and compare with it his engraved representation on the copper. This mirror, it is obvious, must, throughout every branch of Engraving, be often necessary.

Scraper.

Burnisher.

Oil rubber.

Anvil.

Screen.

Mirror.

Note (Z.)

Spanish Engravers.

The following are among the principal, with the dates when they flourished.

A. D.

AT MADRID.

1524. *Joan de Diesa.*
1583. *Vicente Campi*, of Cremona, painter.
1603. *Francisco Lopez*, painter, etched.
1609. *Diego de Astor*, of Toledo.
1615. *Patricio Caxes*, or Caxete, of Arezo.
Horacio Borgiani, of Rome.
1619. *Pedro Perret*, of the Low Countries, pupil, at Rome, of Corn. Cort. (Art. 36.)

1626. *Alardo de Popina.*
1629. *Martin Rodriguez.*
1630. *Vincencio Carducho*, painter, of Florence, etched and engraved.
Juan Schorquens, of Flanders.
1634. *Juan de Courbes.*
1640. *Pedro de Obregon*, pupil of Carducho, etched.
1642. *Francisco Navarro.*
1643. *Maria Eugenia Beer*, pupil of her father, a Flemish painter.
1646. *Francisco Fernandez*, painter, pupil of Carducho above named, etched.
1650. *Cornelius Schut*, of Antwerp, painter, pupil of Rubens, etched.
1660. *Pedro de Villafranca Malagon*, pupil of Carducho above named.
1671. *Martin de Rosswood*, of Flanders.
1680. *Gregorio Fosman*, of Flanders.
1691. *D. Josef Garcia.*
1692. *Luca Jordan*, (Giordano,) of Naples. (Art. 45. and Painting, p. 478.)
1697. *D. Marcos Orozco.*
1734. *D. Andreas Procacini*, of Rome.
1740. *Fr. Matias Irala Yuso*, a Franciscan friar, and several pupils.
1748. *D. Vicente de la Fuente*, pupil of Irala.
1752. *D. Juan Bernabé Palomino.*
Manuel de Chozas,
1754. *Nemesio Lopez*, } his pupils.
D. Juan Minquet,
1770. *D. Carlos Casanova.*
The three *Tiepolo*, of Venice. (Art. 51.)
D. Tomas Francisco Prieto, and his daughter, *Donna Maria de Loreto Prieto.*
1776. *D. Josef Murguia*, pupil of Palomino.
1778. *D. Francisco Casanova*, son of D. Carlos above named.
1793. *D. Juan Fernando Palomino*, son and pupil of D. Juan Bernabé above named.
1795. *D. Simon de Brieva.*
1797. *D. Carlos Josef Flipart*, pupil of Wagner. (Art. 50.)

At Seville.

1584. *Mateo Perez de Alesio*, of Rome, painter; (a pupil of Michel Angelo, Painting, p. 471.)
1627. *Juan Mendez.*
Bartolomé Arteaga.
1634. *Isaac Lievendal.*
1647. *Francisco Heylan*, of Flanders.
1660. *Pedro de Campolargo*, painter.
1672. *Francisco de Arteaga*, son of Bartolomé above named.
1689. *D. Juan de Valdez Leal.*
Matéas de Arteaga, his pupil.
1698. *Juan Perez*, pupil of M. de Arteaga.
1724. *D. Lucas de Valdes*, son and pupil of D. Juan above named.
1777. *D. Manuel Lopez Palma.*

At Valencia.

1654. *Juan Felipe.*
1712. *D. Vicente Victoria*, painter, pupil of Carlo Maratti. (Painting, p. 474.)
1746. *D. Juan Batista Ravanals*, engraved portraits.
1752. *D. Francisco Giner.*
1762. *D. Hipólito Rovira Brocandel.*
Vicente Galceran, pupil of Rovira and of Ravanals above named.
1773. *Tomas Planes.*
1784. *D. Josef Espinós*, painter.
1793. *D. Pasqual Cucó.*

At Zaragoza.

1548. *El Maestro Diego.*
1629. *Josef Vallés.*
1638. *Juan Vallés*, brother of the preceding.
1666. *Juan de Renedo.*
1737. *Fr. Angel de Huesca.*

Note (AA.)

Preparation of copper-plates for Engraving.

In our comparison (Art. 32.) of Wood-Engraving with Chalcography, we omitted mention of the necessary preparation of the copper-plate before the burin can be applied to it. The plate, after being well hammered, is carefully polished with the following substances: 1. with pumice stone, till the inequalities caused by blows from the hammer disappear; 2. with a kind of slate called water of Ayr stone, which removes the scratches made by the coarser material; next with smith's coal or charcoal, which effaces the finer scratches made by the slate stone; (water in considerable quantities is used with the above-named materials;) and, lastly, the final polish is given with an oil rubber. Plates for aquatinta require a higher polish than for other kinds of Engraving.

The tracing ground.

Next, for transferring the outline to this smooth surface, a tracing ground or varnish must be spread over it. Among the many varieties of varnish for this purpose, not differing essentially from each other, the following recipe is given by M. Bartsch: 2 ounces of virgin wax; 1 ounce of asphaltum; ½ ounce of colophonum, or black pitch; ½ ounce of mastic, or Burgundy pitch. After these materials have been well boiled, roll the mass into sticks or balls, and tie up these closely, when quite cold and hard, in bags of taffeta or fine linen. To spread the varnish on the plate, let the latter be warmed over a pan of burning charcoal. The ball being applied to the surface of the warm copper, discharges through the bag the melted varnish; to spread which evenly, use another ball stuffed with wool or cotton, covered with taffeta, till, by dabbing the mixture in a liquid state, a smooth thin coat is laid over the whole. This coat, when quite cold and hard, may be coloured either black or white, thus: for a white ground, prepare a wash of Kremlin chalk, ground perfectly fine in gum water, and pass it over the varnish with a large brush; for a black ground, tie four or five yellow-wax tapers in a bundle, and, while the plate is still hot, hold them lighted under the varnished surface so as that their smoke shall ascend to and touch it, incorporating itself with the varnish.

Transfer of the outline to the plate.

The back of the drawing (of which only an outline is necessary) is next rubbed with the dust of red chalk, and the paper fastened at each corner with bits of waxed pitch (cobbler's wax) to the plate. The artist now traces his outlines with a blunted steel or ivory point, and, on removing the paper, finds them transferred in red to the varnish. This transfer answers equally well for a black or for a white ground. But he may, upon a black ground, vary the process so as to obtain an inverted copy of his drawing, by wetting the paper thoroughly, and laying the other side, which contains the drawing, (outlined in red chalk or black-lead pencil,) upon the varnished surface. He then passes the whole through a rolling press. The damp penetrating the paper discharges during this pressure the chalked or pencilled outline, and transfers it to the plate; the chalk keeps its natural colour, but the pencilled lines have a shining, silvery appearance, sufficiently distinguishable upon the dark ground. After the drawing has been thus outlined upon the varnish, the strokes are retraced by the artist with a sharp etching needle, (Art. 45.) so that the copper becomes slightly indented or furrowed. This done, the plate is again warmed upon a charcoal fire; and, being cleansed from the varnish, shows the outlines, within which the Engraver proceeds to employ his burin (Note B.) and to begin his shadows and hatchings.

Note (BB.)

The atswasser, or fluid for corrosion.

In etching, the strokes and dots, instead of being cut by a tool, are corroded by an acid, generally nitric acid, diluted with an equal quantity of pure rain water. The admixture, however, of water to the amount of four times the bulk of the acid is most convenient. It must be well secured in bottles with a glass stopper. For etching on steel, a mixture, containing equal parts of corrosive sublimate and of powdered alum, (about one quarter of an ounce of each,) dissolved in half a pint of hot water, has been successfully used. The plate is first covered with a resinous substance called the ground, impervious to the acid employed, and the lines intended for corrosion are made by removing the ground with pieces of steel wire called etching needles, of several thicknesses, according to the fineness of the strokes required; of about two inches long, inserted into handles the size of a common lead-pencil, and made of hard wood. For strong coarse lines, oval pointed needles are used. The instrument called the dry point may be used as an etching needle, or *vice versâ*, only that in etching the point seldom requires to be forced so deeply into the metal.

Etching needles.

The plate being polished as described (AA.) is heated over charcoal embers, or in a common oven, and the resinous mixture or ground spread over it, similarly to the mode stated in the above note. We may here observe that, for holding the metal in any case where heating is required, a hand vice or pair of pincers will be necessary, which may be applied on the margin of the plate, so as to keep clear of the work. To prevent scratches, put a slip of paper next the plate. Three sorts of ground have been in general use, the *hard*, the *soft*, and the *common* ground.

The hard ground.

The soft ground.

For the hard ground, used by Callot, (Art. 51.) and called the Florence varnish, take four ounces of very clear linseed oil, such as is required by Painters; heat it in a clean earthen pipkin; then add to it four ounces of powdered gum mastic, and stir the mixture briskly till the whole be well combined. After this, press the whole mass through a piece of fine linen into water, and form it into balls about the size of walnuts, or a little larger. The balls may be then tied up in readiness for use, as described above. For a *soft* ground, take one ounce of white or bleached bees' wax, one ounce of asphaltum, half an ounce of common pitch, and half an ounce of Burgundy pitch. Melt the wax over a slow fire in a pot of glazed earthenware; add to it, by little and little, the rest of the ingredients, stirring the mixture all the time it is on the fire. It must be kept carefully at a low heat, to prevent its burning. When the composition is thoroughly melted and incorporated, take it off the fire, pour the entire mass into a vessel of clean warm water, and knead it into balls of the size already described. Observe that the ground must be made rather harder in summer than in winter. It is hardened by increasing the quantity of asphaltum, or by letting it continue to boil some time after the ingredients have become incorporated.

Lowry's common ground.

For what is called *common* ground, as being most extensively used, the celebrated Lowry, whom we have mentioned (last note to Art. 13.) composed a common ground with three parts of asphaltum, two of Burgundy pitch, and one and a half part of white wax. The asphaltum must be melted first, and the other ingredients added as soon as it is in a state of fusion. The whole, when thoroughly mixed, is poured out into warm water, and kneaded into balls. This ground is excellently adapted to a temperate atmosphere. For very cold weather, the composition may be softened by increasing, in a small degree, the proportion of pitch. For very hot weather, it may be hardened by longer boiling than usual.

Le Bosse's ground.

Le Bosse, a celebrated etcher of the French School, recommends in his Treatise on the Art the following common ground: one ounce of whitest virgin wax, the same quantity of powdered mastic, and half an ounce of calcined asphaltum. Let the mastic and asphaltum be ground separately, and pulverized as fine as possible; and let the wax be melted in a glazed earthen vessel. Sprinkle the mastic gently into the melted wax, stirring the mixture that it may incorporate thoroughly; then sprinkle the powdered asphaltum into it, and continue the stirring over the fire till this ingredient likewise is completely dissolved. Remove the vessel that the composition may cool, and then pour it into warm water to be kneaded as before described.

To spread the etching ground, the etcher proceeds in the same manner as the burinist for tracing his outline. (Note AA.) A dabber, consisting of a little cotton tied up in a piece of silk stuff in a hemispherical form, of about two inches in diameter, is here also requisite. To preserve its shape, he sometimes encloses behind the cotton a circular piece of pasteboard. Let us now suppose the ground spread and cooled on the copper; the next step is to transfer the drawing: this may be done as described above. (*Ibid.*) If transparent paper or oiled paper be used, let the outline be drawn upon it with a pen dipped in Indian ink, mixed with a little oxgall. A piece of thin paper, the same size, may then be rubbed entirely over with red chalk, and placed under the drawing, with the chalked side next to the plate. If the drawing be laid with its inked side downwards, the outlines may be easily traced on the back of it, as the inked lines will be distinctly visible through the transparent paper; in which case, the design on the ground will be reversed, and the future impression from the plate will resemble the original. If a contrary effect be desired, the artist needs only trace his outline over the drawing itself.

How to use the etching point.

The etching needle is next to be used, and the outlines and shadings scratched through the varnish, which, having been blackened in the manner above stated, (*Ibid.*) shows every stroke distinctly on the bright copper. As the heat of the hand would injure and dislodge the ground, a bridge or rest is placed across the plate, and supported by a thin piece of wood at each end. During this stage of the process, whatever portions of the varnish are raised by the needle must be carefully brushed away, and not suffered to stop the lines. And if, on examination previous to the use of the acid, any mistakes or improper strokes have been made, or the ground any where broken up, a composition, called the *stopping* mixture, may be applied. It is composed of turpentine varnish and lamp-black.

Mixture used for *stopping out.*

M. Bartsch's recipe, who calls it covering varnish, (*deckfirniss*,) is grease, yellow wax, and a few drops of olive oil, boiled well together, and mixed with a little lamp-black. For etching on copper as well as on steel, the common Brunswick black of the shops, diluted when necessary with a little turpentine, is employed. The stopping mixture may be applied to the ground with a camel's hair pencil; and, when dry, answers the same purpose as the original ground, being capable either of wholly resisting the acid, or of being traced upon with the needle so as to admit the acid partially.

Etching.

Wall of bordering wax raised round the edge of the work.

The work of the etching needle is now over; and the etcher next surrounds his plate with a wall or border about an inch in height, composed of bees' wax, softened by the addition of one-third of Burgundy pitch, or tallow. This mixture, after having been melted over a slow fire, and increased by a gill of olive oil, is poured into water, and preserved for use in balls or rolls. When applied to the plate, the bordering wax will not work freely until softened in warm water; but may then be easily moulded by the fingers into a ribbon-like shape, for surrounding the margin of the work. The nitric solution being now poured upon the plate to the depth of about half an inch, the acid will speedily begin to bite or corrode the metal in those parts which have been laid bare by the needle. The moment the acid begins to act, bubbles will rise; which, as fast as they appear, must immediately be cleared away with a feather, both from the surface and from such of the strokes as they adhere to. In etching on steel, the peculiar acid used gives out no bubbles, and, therefore, greater care is taken to proportion the strength of the liquid to the exact time for it to remain on the plate. When all the finer lines are bitten to a sufficient depth, the nitric acid is poured off by a spout, which has been left for that purpose at a corner of the border, and stopped for the time with a separate piece of wax. The plate is now washed with water, and the parts which are supposed sufficiently bitten are covered as soon as dry with the stopping mixture.

The work of corrosion is then resumed; the spout again filled up; the acid poured again on the plate; and these operations repeated until all the shadings, according to their respective degrees of strength, are bitten into the metal. The plate, after washing, is next heated; the waxen border taken off; and some drops of olive oil rubbed on with a linen rag, and afterwards with the *oil rubber*, (Note Y.) to remove the ground. Whatever dirt remains in the lines may be cleaned away with spirit of turpentine.

Time required for biting in the copper-plate.

To determine how long the acid should remain on the plate, it is usual, during the intervals for washing the work, to scrape off a small portion of the ground to examine the bitten lines; but the better and surer way is to make a previous trial with the same liquid, to corrode similar lines on a small separate bit of metal, minuting the process from the moment the bubbles appear. Fine delicate work is quickly etched, but the aquafortis requires longer time to eat into broad strokes. For fine lines, the usual time allowed is from half an hour to one hour. But some etchings require a day, or even several days. The influence of weather is remarkable. The same acid on the same copper, in different temperatures, will have different effects. Cold or damp will materially weaken or retard its action; and a change is discoverable even from the sky being overcast with clouds during the process of corrosion.

Walker's method of re-biting.

On examination of the work, either before or after a proof-impression, such lines as are too strong or overbitten may be reduced with the burnisher; or if much too deep, may be rubbed down with charcoal. On the other hand, such lines as are too feeble may be rebitten in the following manner: discovered, it is said, by William Walker, who, with his brother Anthony, flourished in London about A.D. 1760, and engraved jointly with him for the Boydell collection. William, on being one day taunted by his brother and instructor for defective colour in his etching, conceived the project of laying on the coat of varnish, or etching ground, a second time, so as that it should not enter the sunken lines, but only lie as before on the polished surface of the copper. Regarding his experiment as similar to the process by which printers blacken their type, he employed like them his dabber; and this expedient, to his infinite delight, and that of Woollet, to whom he communicated it, succeeded beyond expectation. The operation, however, is extremely hazardous, and requires a delicate and well-practised hand. A little of the etching ground being melted on a separate piece of copper may be taken up by the dabber, and dabbed lightly upon the part to be rebitten in such a manner that it may not enter the former strokes, but merely adhere to the uncut portion of the plate. The dabbed part is then surrounded with a wall of wax, and the acid used in the customary manner. The strokes to be rebitten must first have been entirely cleansed with spirit of turpentine, and rubbed afterwards dry with bread crumbs.

Etching more expeditious than work with the graver.

Number of impressions.

It is calculated that ten etched plates can be executed in the space of time required to complete with the burin a single one. The number, indeed, of impressions that can be taken, must depend on the depth of the etched lines. Acid, much diluted, and applied for a short time to delicate work, can only bite superficially. Coarser and broader lines, having necessarily been submitted for a longer period to the action of the aquafortis, are not so soon effaced in printing, must be deeper, and may be therefore more deeply charged with colour. In general, a well-etched plate is reckoned to furnish 500 strong and good, and the same number of weak, impressions.

Chemical difficulties in etching upon steel.

Etching on Steel.—The principal difficulty in etching upon steel, at its first introduction, was to find an acid which would corrode the lines smoothly, and to a sufficient depth. We need scarcely remind a chemical reader that iron is subject to two states of oxydation—the protoxyd and the peroxyd; and that each of these will combine with acids forming two genera of ferruginous salts—the protosalts, and the persalts. The protosalts contain a larger proportion of oxyd than the persalts; and being liable to pass into this latter state by exposure, for even a very short time, to the air, they become turbid, and deposit peroxyd of iron in a state scarcely at all soluble, except by being digested in hot acid, combined with some deoxydating substance. Hence it is that the action, on steel, of nitric acid diluted with water will not give the same satisfactory results as on copper. For, although it acts very properly at first, while the iron is brought merely to the state of protoxyd, yet, during the necessary exposure to the air, it passes to the state of peroxyd; a portion of which precipitates and fills up the lines of the etching, covering the surface of the steel at the bottom of those lines, and thus impeding and rendering irregular the process of corrosion.

Mr. Turrel's menstruum for biting in on steel.

In 1824, a menstruum for biting in on soft steel was communicated to the Society of Arts by Mr. Edmund Turrel, consisting of a mixture of pyroligneous and of nitric acid, combined with a portion of alcohol. This artist, with scientific sagacity, conceived that the nitrous æther resulting from such a combination would retain the nitrate of iron in its state of protonitrate, and, consequently, prevent the precipitation. His judicious experiment obtained the wished-for result. The proportions of his menstruum are, four parts (by measure) of the strongest pyroligneous acid (chemically termed acetic acid) and one part of alcohol, or highly rectified spirits of wine: mix these together, and shake them gently for about half a minute: then add one part of pure nitric acid. A menstruum, compounded in these proportions, corrodes very light tints in about one minute, or in one minute and a half; and considerable depth and force are attainable in about a quarter of an hour. The process may be quickened or retarded by the greater or less proportion of nitric acid. The plate, when the mixture is poured off, must be instantly washed with a compound of one part alcohol mixed with four parts water. For *stopping out* on steel, the best material, according to the last-mentioned discoverer, is pure asphaltum, sufficiently dissolved in essential oil of turpentine to flow freely from a hair pencil. The foregoing menstruum, as well as others since tried, will succeed with hard steel; but they are by no means so effectual as upon very soft, or nearly decarbonated steel. Engraving, indeed, on steel (so as to compete successfully with copper-plate) must date its origin from the introduction by Mr. Perkins (see last note to Art. 32.) of means for softening steel plates.

Ir. Cooke's enstruum.

In 1825, an improvement of this menstruum was brought forward by Mr. W. Cooke, jun., who was rewarded by the Society with their gold Isis medal. Mix, by gentle shaking, six parts of acetic acid with one part of nitric acid; let this remain only half a minute on the plate, which must, immediately after, be well washed with water, and then dried, but not with the assistance of heat. Stop out the light tints, as on copper, with Brunswick black varnish; and then, for the purpose of washing the oxyd out of the lines, pour on the plate a mixture of six parts water and one of nitrous acid. Let it remain two or three seconds. When it is taken off, let the former mixture be re-applied immediately, without the intermediate ablution in water. Repeat this process for each tint. A temperature of 60°, or higher, is required for the operation.

enstruum Mr. Hum- ries.

In the following year, a similar premium was adjudged to Mr. W. Humphries for his menstruum, as follows: dissolve a quarter of an ounce of corrosive sublimate powdered, and the same quantity of alum, likewise powdered, in half a pint of hot water. Let it cool before use; and, while using it, keep it stirred with a camel's hair brush, taking care to wash the plate thoroughly after each biting. As this acid becomes turbid, it may be prudent, says the inventor, never to use any portion of it a second time. See *Transactions of the Society of Arts*, vol. xlii. p. 55. xliv. pp. 48 and 53.

ching on ass, a ench dis- very.

Etching on Glass.—Although this Art has no connection with printed impressions on paper, it has been usually included by Encyclopædists in the same article with the process we have been detailing above. The discovery appears to have been suggested towards the close of the last century by the experiments of the French Chemists. M. de Puymaurin having covered a piece of glass with a coat of wax, and drawn some figures on it, applied fluoric acid over his performance, and exposed it to the sun. He observed, soon afterwards, that the lines he had traced were covered with a white powder, indicative of the dissolution of the glass. After four or five hours, on removal of the coat of wax, he found an etching perfectly formed on the glass. M. de P. tried several varnishes for a ground, and found a strong varnish composed of equal quantities of drying oil and mastic the best. The glass, before applying it, must be thoroughly cleaned, and heated until the hand can scarcely be held upon it. The varnish is then applied lightly, to cover the glass, and laid smooth by the dabber, as in etching upon metal. The smoke of wax torches is next used, to blacken the ground; and the intended etching traced upon it. But in tracing the design, the glass plate must be supported on a glass pane, fixed like a desk, so as that the light may show through the lines made by the etching point. The fluoric acid is not applied in its simple form, but is exhibited as found in the fluor or Derbyshire spar, finely pulverized, and is expelled from the spar in a gaseous state by the addition of a little sulphuric acid. The fluor spar must, therefore, be enclosed in some vessel capable of resisting the acid. The fluoric acid, for instance, which is distilled in a glass retort, loses its strength, and bites unequally from the admixture of the silicious earth of the retort with the sulphuric acid. An improved silver apparatus, therefore, is recommended. Also, the glass to be corroded ought to be placed under some apparatus which will prevent the escape of the gas. The appearance of the etched parts is like that of ground glass, and forms an excellent contrast with the remaining polished surface. All sorts of glass will not serve equally well for etching. English glass, in the composition of which there is a large proportion of lead, is easily acted upon by the acid; but the smallest defect in the varnish admits the corrosive matter, and, by solution of the calx of lead, a disagreeable tinge is given to the glass. Plate glass is the fittest material: not that with a green but with a white reflexion. When the weather in summer is clear and serene, a piece of plate glass, varnished, traced, covered with the acid, and exposed to the sun, is completed in four or five hours. In winter, the operation of biting requires four days, and must then be assisted by a moderate and regulated heat, like that of an oven or stove.

Note (CC.)

Instruments for punching

The process, as described by M. Bartsch, (*Anleitung, &c.* vol. i. sect. 62.) is as follows: After the outline has been traced on the copper, according to the method already stated, (Note AA.,) the operator is provided with small rods of hardened steel, three or four inches in length, and about one-twelfth of an inch thick, having one end in the form of a truncated cone. This truncated extremity is either provided with small pointed teeth, placed close together, or is indented with small holes; but in some, the instrument terminates in one sharp apex, like the dry point. With these small rods of steel, which are termed *punches*, the intended shadings and lines of the work are beaten by the strokes of a small hammer into the plate.

Number of impressions from punched plates.

The number of prints which may be taken from a plate, wrought in this manner by punching, depends upon the depth of the holes or indentations; but it will be scarcely ever found to yield as many impressions as a plate slightly etched. There are very few specimens of this kind of work. The prints are distinguishable by being composed entirely of dots, greater or less in magnitude, and round or oblong in form, but never so sharp and clear as those from the dry point, since the printing ink must adhere unequally to the rough surface thrown up by the punch.

Note (DD.)

Instrument for mezzotinto.

The cradle, or grounding tool, is an instrument in the form of an axe, (plate i.,) having teeth placed close together, like those of a small-tooth comb, in lieu of an edge. The term *berceau*, or cradle, is given to this instrument, from the similarity of its motion when in use to that of a cradle when rocking. The supports of a child's cradle must, for the purpose of rocking, take a curved form like the edge of this instrument, or of an axe. The curve of the graving tool should be a portion of a circle, of which the radius does not exceed six inches. If too much curved, the cradle would dig too deeply into the copper; if too little, the plate would not be sufficiently indented.

By referring to our remarks on chiaroscuro (PAINTING, p. 580, Art. 290, *et seq.*,) the reader will perceive that the expression *mezzotinto*, or middle tint, is only applicable to this method, as providing means by which the really middle tints may be obtained through the subsequent use of the scraper. The first and the peculiar part of the process is to cover the plate with the extreme dark, No. 5. (PAINTING, *ib.*) The plate, after being polished and prepared as for other work, is divided equally by lines drawn in soft chalk, parallel to each other. The interval between the lines should be about one-third the length of the face of the cradle or grounding tool, which is then to be placed between the two first lines at the top of the plate, and passed forwards *in the same direction* with them. The operator must hold the tool as steadily as possible, and quite upright, pressing upon it with a moderate force, and rocking it from end to end, parallel to these two guiding lines, till he has completely hacked all that part of the Plate between them. He next repeats the same operation with respect to all the other lines and intervals, till the instrument has passed over the whole Plate, rendering it uniformly rough throughout. Other lines must now be chalked upon the Plate at *right angles to the former*, and proceeded with in the same manner. They will form squares with the lines first drawn. When the Plate has been again passed over by the cradle in this direction, it is next to be proceeded with in the same manner, *diagonally;* the diagonals being drawn to the squares in question. This done, the operator next employs his instrument upon the diagonals drawn, as follows: Let each square be supposed divided into three equal parallelograms, as in pl. 1, fig. 9. The diagonals to these parallelograms will then form two other sets of lines for the guidance of the grounding tool: and to obtain them, nothing further is required than a division of two opposite sides of each square into three equal parts, with lines intersecting them, as expressed by the dotted lines in fig. 10. A Plate, entirely covered with these several crossings worked by the cradle, is said to have undergone *one turn*. But, in order to procure a very dark and uniform ground, the Plate must undergo a repetition of all these several operations for above twenty times; for which purpose, the Artist must always begin each turn by starting from the same point and in the same direction, that is to say, between the same parallel guiding lines as at first; so that this preparatory work employs much time and pains. According to M. Bartsch, a Plate of two feet long and eighteen inches broad requires the labour of three weeks to produce a fine jet black impression; and, for a larger Plate, even a month or more is required. We are disposed to think that, in this age of mechanism—the "age of steam"—some method might be devised for abridging this manual labour, and accomplishing with equal, or perhaps superior, accuracy the same results.

Preparation of Plates for mezzotinto.

The fineness of the grain thus obtained depends upon the size of the teeth in the graining tool. Cradles, having broad, coarse teeth, enable the Plate to furnish more impressions, and give the dark shadows a softer black: but then the dots at each crossing are, in such a case, visible in the lighter tones; and produce difficulties, or, at all events, a disagreeable effect in the minute details of a picture.

Mezzotinto scrapers.

Their form and uses.

In describing former methods of Engraving, we have considered the Plate of copper or of steel (previously to any lines etched or engraved upon it) as resembling a sheet of white paper, on which the Artist is to draw and work up his intended effects by lines of various strength or delicacy, leaving only those portions of the surface blank or untouched which are designed for *extreme light*. (PAINTING, p. 580, art. 290—294) The method we are now considering is the complete reverse of the former. He must now look upon his Plate as if it was a sheet of drawing paper totally black. His business, therefore, now is to arrive at the middle tints, and extreme lights, by removing, more or less, the graining ground from the Plate; and this he effects with scrapers, similar in form to the instrument before mentioned, (Note B.) but of different sizes, that is to say, with lancet points of different widths, according to the degree of nicety or minuteness required. The masses of strongest light are first scraped and rendered pretty smooth; and some parts, such as in a head, the tip of the nose, &c. are burnished. The burnisher is likewise applied to such gradations of shading as go off into extreme light in their upper part, but are brown (that is to say, scraped to a middle tint) below. The next degrees, or rather diminutions, of shading are then scraped; and after them, the reflected lights. At this stage of the work, the Plate may be blackened, to ascertain the effect, with a printer's blacking ball; and then the operator is to proceed again with the scraping tool, taking care always to begin from those parts of an object where its strongest lights are to appear.

Number of impressions from copper-plates.

If the graining of a scraped copper-plate be not particularly fine, it will furnish one hundred, or even one hundred and fifty impressions; but after the first one hundred and fifty impressions have been taken from it, the practice is to work it again partially over with the graining tool, and afterwards with the scraper. In this way, impressions by fifty at a time may be repeated in succession, so that the same Plate, says M. Bartsch, has frequently yielded three or four hundred impressions.

Number from steel.

Mezzotinto on Steel. This discovery enables the Artist to obtain for his work eight or ten times the number of impressions as from copper-plate. The same mode of operating is adopted as on copper-plate; only, greater strength must be used for laying the mezzotinto ground. A greater number of *ways* is likewise required. A *way* is the technical word for going entirely over the plate with the grounding tool. Mr. Lupton, who obtained in 1822 the gold Isis medal from the Society of Arts for an engraved portrait on steel, remarks, in his letter to the Society, that he has used as many as ninety ways on some steel-plates; whereas, on copper, the usual number is from twenty-four to thirty-six or forty. Great care is necessary to prevent the Plates taking rust.

Origin of mezzotinto on steel.

The suggestion of mezzotinto from steel was made in 1812 by the late Mr. James Watt to one of our most eminent living Engravers, who subsequently communicated in a letter, published by the Society of Arts in their Transactions, (vol. xlii. p. 55,) some interesting particulars on the subject. The writer remarks that his attempts upon hard steel, in consequence of Mr. Watt's suggestion, were unsuccessful; but the subsequent production by Mr. Jacob Perkins of Plates of steel, sufficiently decarbonized and softened to receive impression from the grounding tool, enabled him to accomplish every thing required. He adds that, in Engravings upon steel, "the tones are far better defined than those obtainable from copper: the clearness of the lights carried to much greater perfection; and the darks distinguished by superior richness. Although the process is much longer and more tedious on steel than on copper, yet, when completed, it is so perfectly satisfactory as fully to reward the additional labour." See Letter from Mr. C. Turner to Mr. Solly, published as above stated, and bearing date Oct. 14, 1824.

Its advantages.

Note (EE.)

Softness the characteristic of mezzotinto.

The advantage of mezzotinto Engraving consists in the soft gradations of light and shade. As no lines nor strokes are visible, Prints of this kind appear executed with a brush, and finished with the most delicate softness. Naked figures, and every soft or smooth object, like hair or fine drapery, may be faithfully and perfectly expressed. The only difficulty consists in representing the lesser details, for which purpose the scraper is insufficient, especially in a coarsely ground Plate.

Clearness not always easy of attainment.

Some Artists have endeavoured to give the requisite decision to the outline by means of the burin or by etching; but their attempts have been unsuccessful, since the usual harshness of the lines thus superadded forms too strong a contrast with the softness of the mezzotinto, and, consequently, cannot easily be brought to harmonize with the rest of the performance. The only person, according to M. Bartsch, who has successfully introduced a series of lines and dots into some Engravings of this kind, is our venerable Countryman, Richard Earlom. But his lines and dots are not so much employed to define the outlines (especially in the masses of light) as here and there to give greater force where the representation demands it, and to produce a deeper black, for which the graining alone, even when left quite rough, is insufficient. For this purpose, his series of lines are not, as might be supposed, deeply cut with the burin, but etched in so light and easy a manner, that their masterly freedom admirably harmonizes with the velvet-like softness of the mezzotinto.

Earlom's method clear and harmonious.

Note (FF.)

Method of Le Blon.

As mezzotinto is better calculated than any other style to imitate the gradual blending of colour produced in Painting with a brush, this advantage must be increased if a diversity of colours be superadded; and thus, the highest aim of the Engraver, namely, a perfect imitation of Paintings by renowned Artists, be obtained. This additional property causes the preference which is awarded to Le Blon's method. The methods of Chalcography, by means of the burin, the dry point, the etching needle, or the mezzotinto scraper, hitherto described, are certainly capable of expressing in a considerable degree the beauties of a Picture. We admire, in many works so executed, a subject judiciously chosen, a composition cleverly arranged, an outline tastefully and correctly drawn, an effect of chiaroscuro beautifully given: but we miss the charm of varied colouring, which not unfrequently constitutes the chief excellence of a Picture,—an excellence which, in flower-painting, or subjects of still life, is indispensable. Le Blon's system seems calculated for supplying this desideratum. It multiplies the original Painting in every particular.

Previous attempts at printing in colours by means of only one Plate.

Attempts were made at coloured impressions of Engraving by *Peter Lastmann*, the sometime instructor of Rembrandt, even as early as the year 1626; by *Peter Schenck*, an Engraver of Amsterdam, in 1680; and by an English engineer, named Taylor, in the service of Frederic the Great: but, as these performances were merely etched in lines, and were executed by transferring the colour to only one and the same Plate, they could never attain the rich effect of a Picture. For this reason, no further endeavours of this kind seem to have been made. M. Bartsch, indeed, alludes to some mezzotintos, published some years since, that bear some resemblance to those of Le Blon. But as these were executed by means of only one Plate, previously painted over with the different colours required, the dots or little crossings of the mezzotinto (see Note DD.) appear uniformly of one colour, (namely, that which the Printer has given to each portion of the Plate before printing,) instead of exhibiting that variety, richness, and transparent effect, which we proceed to describe in the method of Le Blon. Such Prints as the above do not blend their tints effectually, especially in the lights, where many traces of the white paper may be detected, and are seldom so perfect but that they require re-touching here and there with a brush; whereas Le Blon's impressions, on the other hand, are almost wholly covered with colour, and, if properly executed, come out in a perfect state from the hand of the pressman.

Three or more Plates required for Le Blon's method.

For every Picture to be imitated in Le Blon's style, at least three Plates are requisite,—one for red, another for blue, and the third for yellow. In some cases, a fourth Plate is also wanted for black. The mixture of these three primitive colours produces other three; red and yellow make orange; red and blue make violet or purple; blue and yellow make green. The mixture, moreover, of the three primitives—red, blue, and yellow—together in *equal proportions*, produces black; and their mixture, in *different* proportions, produces every other possible colour. (See PAINTING, Note to Art. 285.) The degree of strength or of paleness (*Ib.* Art. 284) in the tone of the primitive colours, or for that of the compounds produced by them, will depend upon the graining of the Plate, and whether it be deep or shallow. In places, for example, where the graining is left quite rough, and, consequently, where the colour sinks in deeply, a darker and stronger tone is produced in the impression. Where, on the contrary, the Plate has become smoother by the application of the scraper, and the colour but superficially imbibed, paler, lighter, and softer tones will be obtained. It naturally follows that each of the three Plates in question must be differently worked by the Engraver. For instance, the Plate intended for blue must be left quite rough in those places which are to appear perfectly blue; or, secondly, the Plate must be more or less scraped in parts where the blue is to blend with the colour of another Plate; or, thirdly, the Plate must be polished to a degree of perfect smoothness where the blue is not to appear. The same rule is to be strictly followed for each of the other Plates.

The colours used for printing must, says M. Bartsch, be transparent, so that one may show through the other. They may be ground with nut oil, but poppy oil is preferable. Both kinds should be mixed with one-tenth of drying oil. Prussian blue, yellow ochre, and red lake, (the latter mixed with two parts of carmine,) are the colours employed. If a black Plate is necessary, printing ink is used. The blue Plate is used first, the yellow next, and, lastly, the red. The impressions may either all be coloured blue, then yellow, and afterwards red; or each sheet may be separately printed off at once. The latter method is preferable, as the colours then succeed each other in a damp state, and are more readily blended.

Note (GG.)

Chalk-Engraving or Dotted Etchings.

The preparation of the Plate, by laying the ground, tracing the subject, &c., is the same here as for etching. (Note BB.) This style may be considered a method of etching in dots, instead of lines. The dots are intended to resemble the grain produced by a chalk crayon upon paper. For the strokes made with the chalk will be found to touch the paper only at certain intervals, and on certain eminences, more or less apart, according to the description of paper used. According, therefore, to the quality of these strokes in the drawing to be engraved from, the size and distance of the dots or points made through the etching ground must be determined. In representing the hatches of the drawing, and in giving to each object its proportion of light and shadow, a distinction also must be preserved between those hatches which mark the perspective of the object, and those which characterize its surface. The principal hatches require, of course, to be more strongly marked than those which are subordinate; and the fainter or middle tints, if etched, must be marked lightly. But these latter may be left to be finished with the dry point or graver after the etching ground is taken off; and by this method greater softness and clearness will be obtained. Great care must be taken not to corrode the lighter hatchings too deeply. When these are sufficiently bitten they may be stopped out with the *stopping mixture*, (turpentine varnish and lamp-black, Note BB.) and the solution of aquafortis again applied, to *bite in* or corrode the stronger parts. At this stage of the process, if the dots which compose the shading burst into each other, the operator need not fear that they will injure the work, unless they form too hard a spot, or too deep a black. When the etching ground is removed from the Plate, it will be necessary to interstipple the flesh, or softer parts of the work, with points made on the pure copper by means of the burin or dry needle. The strongest shade will also require additional strength, and must, therefore, be deepened by slight touches of the graver. For making dots with this latter instrument, (Note BB.) a common practice is to change its situation in the handle, so that the belly or convex part of it, which was lowermost for cutting lines, becomes uppermost for dotting. Then, by having turned the handle to fit the hollow of the hand as before, the point of the burin acts upon the copper from a greater elevation, or, as mechanists term it, with a better purchase. As dots only, and not strokes, are required, the tool is managed in this position with greater ease and freedom. In this manner the Plate is to be worked and dotted throughout, and, when one covering of dots is completed, and cleaned off with the scraper, another covering must be inserted, until, by this operation, (repeated as often as is necessary for a perfect imitation of the drawing,) a proper grain and sufficient masses of shade are produced.

Finished with the graver and dry point.

Great patience and much practice are necessary to success in this way. Many expedients and contrivances to save this trouble have been in use. For large subjects, and also where only a general effect is wanted, and where great exactness is not required, various other instruments have been used, such as wheels, having single or double rows of teeth at their edges, or cradles resembling a grounding tool for mezzotinto, (Note DD.) only made with peculiar teeth, so as to produce points or dots. Numerous tools were invented by the chalk Engravers in France, where chalk Engraving originated. A complete set of them is said to amount nearly to forty different articles. Of these, however, M. Bartsch mentions only the following; 1. an *etching needle*, in order to dot the outlines and parts intended for etching; 2. a *double needle*, or one with two points; 3. a *triple needle*, with which three dots may be made at once,—this instrument, together with Nos. 1 and 2, may be made with points differing in thickness, according to the size of the dots required: the points must be rather blunted; 4. the *mattoir*, a sort of punch, (Note CC.) one end of which, in a cubical form, is furnished with small uneven teeth, irregularly placed and blunted: it is fastened to a wooden handle; 5. a similar *mattoir*, *without a handle*, to be hammered upon the Plate after it has been etched, and the etching ground cleaned away; 6. the *roulette*, a small roller or cylinder of steel, (between one-eighth and three-sixteenths of an inch in diameter,) which is covered with small, closely compacted, delicate points or teeth, and which revolves upon an axis attached to a handle of wood: this instrument also varies in its breadth and thickness, and in the fineness as well as closeness of its teeth; 7. a *double burin*, with which two dots or pecks may be made at one time.

Variety of tools used by French artists.

It will sometimes happen, in etching the work, that parts intended to be dark will fail of their proposed effect, and the failure be unperceived until the etching ground has been removed. In such cases, the process of re-biting (Note BB.) may be advantageously practised.

Number of impressions.

Plates, engraved in this style, commonly yield about five hundred or six hundred impressions. Common printing ink is used for black, and burnt sienna for red: this latter, as also the various mineral colours employed for imitation of chalk drawings, should be ground in poppy oil. Drawings, made with chalks of different colours, may be imitated, if a separate Plate be provided for each colour. There are several excellent French imitations of chalk drawing on blue paper, by using two Plates, one to print the black chalk effect, the other to give that of the white chalk.

Note (HH.)

Difference between the English and French style.

This method only differs from the last in the superior neatness of its execution. The English style, says M. Bartsch, is distinguished from the French by having its dots small, round, and closely placed together like those executed with a punch, (Note CC.) but much more distinct. In the French Engravings, the dots are irregular, rough, sharp, either coarse and too far apart, or they take the opposite extreme, running into each other from being too close.

Plates, engraved in the English manner, furnish nearly five hundred good, and the same number of weaker, impressions. They are hot-pressed, and receive the same colours similarly prepared with those for the last-mentioned method.

Note (II.)

Method of Le Prince wholly etched.

The bistre, or aquatinta style, called Le Prince's method, is wholly etched. The outlines are first etched in the manner before described. (Note BB.) After this operation, the Plate is thoroughly cleansed, and again washed slightly with common etching varnish. When the varnish is dry, those portions of it, where the shading in aquatinta is intended, are to be cleanly removed from the Plate by the application of a sharp fluid, composed of olive oil and spirit of turpentine, mixed with lamp-black or finely powdered pine-tree soot. This fluid, which is laid on with a brush over the shaded parts, and which is mixed with the black in order to make

How to lay the aquatint ground.

Biting in.

the confines of shadow more visible and more distinctly executed, so completely removes the varnish, that it may be immediately wiped off with a clean linen rag. The whole Plate is next covered with finely powdered white resin, sifted all over it through a fine hair sieve. In order that the powder may not be adhesive, it should be previously wetted with a mixture, composed of soap, sugar, and water. The superfluous resin is then shaken off, and the Plate held over a charcoal fire until the small particles of resinous dust dissolve and adhere to the bare copper. This change is observable as soon as the dust, which was previously white on the places covered with varnish, begins to turn brown, and also when the outlines previously concealed by the dust begin to be visible. As this change takes place, the Plate must be removed from the fire, and allowed to cool; otherwise the little grains, instead of merely adhering to the copper in a granular form, would spread and liquidate into a sort of varnish, and impede the progress of the aquafortis, for which the Plate is now ready. The solution should not be very strong, else the innumerable small grains would be detached from the copper, and the work be spoiled. The first tone of shading being completed, the Plate is cleaned, washed over again with varnish as before, and the second tone worked into it. This process is to be repeated until all the requisite tints are produced. The artist may, according to his fancy, either begin with the strongest shades, adding the weaker ones by degrees, or may first *etch in* the more delicate tints, and afterwards go over them until he obtains the darker shadows. The first of these modes is generally preferred.

Other ways of laying the ground.

Some variation in the manner and routine of these operations is occasionally practised. The powdered resin, for very fine work, may be enclosed in a bag of fine muslin, and shaken against a piece of stick at a considerable height above the Plate, in order that a large cloud of the resin dust may be formed, which, in descending, may spread uniformly over the surface previously to heating the Plate: and the heating may be more gently and gradually effected by holding under it some lighted pieces of brown paper, and moving them about till every part of the powder shows itself sufficiently melted by changing colour. After the Plate is cool, such parts of the work as are to come out perfectly white are covered or stopped out with the stopping mixture, (Note BB.) diluted sufficiently with turpentine, so as to work freely in the hair pencil. The margin of the Plate must also be stopped out. Then follows the process of *biting in*, which is repeated according to the number of tints required.

Stopping out.

There is extreme difficulty, however, in some cases, of stopping out, round the finishing touches, leaves of trees, and light sharp projecting edges of other objects, by only the mode just stated. Another very ingenious process has been contrived to overcome this difficulty, so as that the finishing touches of the drawing may be perfectly imitated and copied on the Plate with the same ease and expedition as they were laid on at first in the drawing itself. Fine washed whiting is mixed with a little treacle or sugar, and diluted with water in the pencil so as to work freely; and this is laid on the Plate when covered with the aquatint ground. in the same manner and on the same parts as ink in the drawing. When this is dry, the whole Plate is varnished over with a weak and thin varnish of turpentine, asphaltum, or mastich, and then suffered to dry: when the aquafortis is poured on as in etching, (Note BB.) the varnish, by the action of the corrosive fluid, will immediately break up in the parts where the treacle mixture was laid, and expose all those places to the action of the acid, while the rest of the Plate remains secure.

A better method of laying the ground.

There are disadvantages, it must be owned, which attend this mode of engraving aquatinta, and cause it to be only occasionally practised. Plates, thus engraved, do not print many impressions before they are worn out; and as different degrees of coarseness or fineness in the grain are frequently required for producing a complete effect, the process hitherto stated is often insufficient. A second method, therefore, of producing the aquatint ground is very generally resorted to. Some resinous substance, as common resin, Burgundy pitch, or gum mastich, is dissolved in spirits of wine, and this solution poured all over the Plate, which is then held in a slanting direction until the superfluous fluid drains off. The Plate is next laid down to dry, which it does in a few minutes; and if the surface be examined through a magnifier, the observer will find that the spirit, in evaporating, has left the resin in a granulated state, or rather that the latter has cracked in every direction, still adhering firmly to the copper. The spirit of wine used for the solution must be highly rectified, and of the best quality. Resin, Burgundy pitch, and gum mastich, when dissolved in spirits of wine, produce grains varying in appearance and figure, and are sometimes used separately, and sometimes mixed in different proportions, according to the taste of the operator. In order to produce a coarser or finer grain, it is necessary to use a greater or smaller quantity of resin; to ascertain the proper proportions, several spare pieces of copper are provided, on which the liquid may be poured, and the grain examined before it is applied to the Plate for engraving. The liquid, after the solution is made, must stand undisturbed for a day or two, until all the impurities of the resin have settled at the bottom. Straining it through linen or muslin will not answer, as, in straining, it becomes filled with hairs or other obnoxious matter, which ruins the grain. The room also in which the liquid is poured on the Plate must be perfectly still and free from dust, which, wherever it falls on the surface (if moist) of the Plate, causes a white spot, which it is impossible to remove without laying the grain afresh. The Plate must likewise have been previously cleaned with the greatest possible care by the application of a rag and whiting, as the smallest particle of grease will produce some streak or blemish. In slanting the Plate, to draw off the superfluous fluid, there will naturally be a greater body of the liquid towards the lower than at the higher edge of the Plate. The grain, therefore, is always coarser at the side of the Plate which is held lowermost. The coarser side is usually kept for the fore-ground, as being that portion of a drawing which has generally the deepest shadows. In large landscapes, sometimes, various parts are laid with different grains, according to the nature of the subject. Moderately coarse grains better answer the purposes of this art than very fine ones, since the particles, when very small and near each other, are liable to be soon disturbed by the aquafortis, which of course corrodes laterally as well as downwards. Indeed, in any case, the acid, if left too long on the Plate, will eat away the grain entirely. Let the artist have several bits of copper laid with aquatint grounds, the same in kind and in grain as those to be used, and let the aquafortis remain for different lengths of time on each. He may then examine and judge of the tints produced, in one, two, three, four minutes, or longer; and may vary the strength of the solution according to circumstances. A magnifier is useful to examine the grain, and to observe the depth to which it is bitten in. No proof of the Plate can be obtained till the whole process is finished. In re-biting, or etching over again any part already subjected to the aquafortis, the new grain to be laid on should be coarser than the first, otherwise it will be apt to lodge only in the dots or holes previously etched, and not upon the heights only, as is necessary in order to produce the same grain.

To determine how long to leave the acid on the copper.

New grain for re-biting coarser than the first.

Deficiency in aquatinta.

This style of engraving is, as we observed, chiefly adapted for imitation of sketches, washed drawings, and light subjects; but is not at all calculated to produce Prints from highly finished Pictures. Its resemblance to drawings, however, only extends to the imitation of abrupt shadows boldly executed: it does not succeed in those which are softly shaded off as they approach the lights. The Plates seldom give more than two hundred good impressions. They must be hot-pressed and treated with care.

Extract from Stapart's "Art of Engraving with a Brush on Copper." A. D. 1773.

The Treatise by *Stapart*, published in 1773, (referred to in the first note to Art. 66.) and entitled "The Art of Engraving with a Brush on Copper," gives the following account of his process: "After etching his outline he covers his Plate with a transparent varnish, through which the etched outlines are to be distinctly visible. The varnish, while yet in a fluid warm state, is then strewed with rock-salt, sifted over it through a fine hair sieve. The Plate is next held over a charcoal fire, till all the grains of salt penetrate to the copper through the varnish. The Plate is now cooled and dipped in water to dissolve the salt. An infinite number of small holes will be perceivable through a magnifying glass; and through these holes the solution of aquafortis is to find its way for corroding the Plate as in etching. The lights, however, must be first stopped out by another substance, which the writer terms the colophon varnish, (such as is used for lackering,) mixed with a little pine-tree soot. When the weakest shadings have been bit in sufficiently, the aquafortis is poured off, the Plate dried, and the first or weakest tone of shading stopped out preparatory to a second application of the corrosive liquid. This operation of alternately stopping out and etching is then repeated, till all the proper gradations of shadow are completed."

The true discoverer, says M. Bartsch, of the above method described by Stapart, appears to have been *Peter Floding*, by whom two Plates after Monet and De la Rue, published in 1762, are etched, as M. B. conceives, with seasalt or rocksalt, and who styles himself *Novi hujus primarum delineationum conservandarum, et multiplicandarum methodi auctorem.*

By some artists, a mixture of seasalt and rocksalt, with sal-ammoniac and syrup of old honey, has been used. This mordant, being applied with a brush, either to the clean copper or to the varnished surface after perforation by the salt, produces gradations of shadow delicately rounded off, as may be observed in the clouds of some of the Plates of *Ploos van Amstel*. This composition has been likewise used after the first two tints were produced by the solution of aquafortis, in order to add the third darkest tint. To make the latter still darker, some have used a solution of silver in spirit of saltpetre or of copper; or, thirdly, aqua regia, any of which substances may be applied with a brush. But the process called Le Prince's method has been preferred to every other.

Note (KK.)

For Aquarilla the outline only is etched.

Instruments for this style, and their uses.

For this style of the Art, as well as for that of Le Blon, (Note FF.) as many Plates are required as there are colours to be used. These are generally black, blue, yellow, and red; and from these may be derived the other compounds. Etching is here only employed to define the outlines of the figures. When this is done, and the Plate cleaned, it is worked upon with rollers, (roulettes,) which, as respects the graining only, differ from those used in chalk Engraving. (Note GG.) by being altogether finer, in consequence of the difference in the teeth of the instrument. Some Engravers use another instrument resembling a common thick etching needle, but having, instead of the point, a little wheel with spikes affixed to it. This tool is used with both hands: the right hand keeps it in a perpendicular position, while the middle finger of the left hand turns the wheel. The tools are worked on the metal in a dry, that is, unvarnished state.

Its advantages.

As the rollers employed for this work may be pressed much or little, according to fancy, their operation possesses an advantage over the last-mentioned or aquatinta style. Not only the abrupt tones of shade, as in aquatinta, (Note II.) but also the soft gradations of light may be produced, and, consequently, a perfect imitation of finished drawings. The softer shadings appear as delicate in the impression as if they were washed in with Indian ink. They much resemble those of aquatinta, only traces here and there may be detected of little furrows, almost like those we meet with in a finely grounded mezzotinto. In the dark shadings, the dots of the coarser grained roller are distinctly perceivable. But the distinguishing characteristic of this style appears in those shadows, as before observed, which vanish and disappear by insensible gradation into the lights, and which cannot be represented on metal Plates by any of the other methods in imitation of water colours. When the drawing to be engraved is of but one colour, a single Plate will suffice, but four or five Plates may be requisite for coloured drawings. Plates executed in this manner furnish about two hundred good impressions.

Number of impressions.

Note (LL.)

Principles of Lithography.

Nearly all kinds of stone imbibe both watery and oily fluids; but the portion of a stone occupied by one of them of course precludes the admission of the other: consequently, where a slab on any part of its surface has been greased, it ceases to soak up water, and *vice versâ*. Upon a stone partially greased, and having its remainder saturated with water, a greasy application can only take effect where grease has been before: let, therefore, an oily substance, such as printer's ink, be rubbed over a stone so prepared, the applied substance will adhere only in those places to which it bears an affinity; and whatever lines or forms may have been originally traced with the greasy material will become more distinct and prominent, and may be charged with a sufficient quantity of colour, to be again taken off the surface by means of pressure, and transmitted to paper. On these few and simple principles is founded the art of printing from stone, or lithography.

Stone from Kehlheim and Solenholfen.

Preparation and quality of the stone.—The stone should possess a perfectly level surface, with a fine uniform grain, and should readily imbibe moisture. The best sort is a species of limestone, or calcareous slate, generally cut into square slabs, smoothed on the upper side, and employed in Germany for floors of churches, cloisters, courts of palaces, as well as private houses, &c. It is known in Germany by the name of Kehlheim stone, having been brought from quarries near a town of that name on the Danube. It abounds in the district between Dietfurt and Pappenheim, and along the Danube down to Kehlheim. The quarries at Kehlheim, it is said, are exhausted, and the traffic in lithographic stone now chiefly centres in the village of Solenholfen, in the district of Monheim, three leagues from the town of Neuburg, on the Danube. When the ground is uncovered to the depth of from ten to fifteen feet, the stone appears in horizontal strata, of various thicknesses and qualities. The stone Plate requires to be from two to three inches in thickness. It is composed of carbonate of lime, in which a small portion of iron is present, and the best is generally to be found in the vicinity of iron mines. Oxide of iron appears to bear a strong affinity to grease, since the best impressions have been obtained from stones whose yellow colour indicates the presence of iron. A solution of iron has been consequently used by French lithographers for washing the stone, called by them, *la preparation qui fait jaune*, and by us "yellow facing;" but it causes too strong an affinity to the grease, clogs the Plate with colour, and produces what are termed *smudged* Prints. In colour and texture, Bath stone more nearly resembles that of Solenholfen than any other to be found in England. But it is inapplicable for any but the coarsest work. An extensive search was made between A. D. 1817 and 1819 by M. Engelmann and the Lithographic Society, throughout the Volges and Jura, in the hope of discovering quarries; but, though these mountains, and the Jura in particular, are principally calcareous, and might furnish great abundance of the kind of stone, yet it was found so unequal in formation and colour, and so interrupted by fissures, crystallizations, petrifactions, and other blemishes, as to furnish no Plates of sufficient dimensions to recompense the labour of extracting it. The same objections apply equally to the lithographic stone of Swisserland, France, Italy, and the British isles. The Lithographers of Europe depend for their supply upon Bavaria alone, where, however, no want of the material for centuries to come need be anticipated.

Other countries yield Lithographic stone, but not in Plates of proper size.

Substitutes for stone attempted.

From the difficulty and trouble attending the safe and ready conveyance of stone Plates, other contrivances more portable and available have been attempted. The ingenious Senefelder has invented various substitutes and compositions in imitation of the stone, some of which have been employed in Germany; but, although useful as temporary expedients, they yet call for much improvement, and are still inferior in point of consistency and manageableness to those from the laboratory of Nature at Solenholfen.

Preparation of the stone Plate.

For preparing the surface of the stone tablet, M. Bartsch, to whom we are indebted for most of our technical details, gives the following directions: Two slabs with their flat surfaces laid together, and having some clean silver sand and water between them, are rubbed backwards and forwards, until the sand is crushed, and, by wearing away the stone, becomes a thick paste-like substance; more sand must then be added, or the old quite washed off, and fresh sand and water applied. The rubbing must be continued till both surfaces are perfectly level. Two stone Plates are thus polished at the same time. The polisher, according to the sort of work to be finally printed from the stone, makes the surface more or less rough, and to produce a finer grain, strews fresh sand, continuing to rub the stones till the larger particles of the sand become rounded, but not quite crushed. When perfect smoothness and glossiness are required, the foregoing operation is persevered in, and ceases only when the sand meets no longer with any resistance from the stone surface, which is then rubbed with pumice and water till it shines and reflects the light. Upon the accuracy of this work of the polisher, the future success of the Lithographer in a great degree depends. No inequalities must remain on the surface, otherwise no clear impression can be taken, or the stone may be fractured in the press. The smoothed face of the stones after graining or polishing should be carefully washed with a sponge in pure water, to remove the grit, and then left to dry.

Lithographic chalk.

Materials for drawing on the stone.—The materials for inscribing the stone are, either a preparation of chalk, to be laid on in a dry state like a crayon on paper, or a kind of ink to be used with a pen or hair pencil as in writing or drawing. Among the various receipts given by Senefelder for Lithographic chalk, he considers the best to consist of eight parts wax, four of soap, and two of lamp-black. These ingredients, after sufficient concoction, should be poured slowly upon a marble slab or iron plate, to form a mass about as deep as the thickness of the intended crayon. This substance is next pressed under another Plate, to render it sufficiently hard and compact; and then, while it is yet warm, divided into strips, which are afterwards separated when perfectly cold. The lithographic chalk may be made harder by a greater proportion of wax, or softer by increasing the proportion of soap. Very good crayons, of a medium stiffness, may be made of four ounces of wax, four of chalk, four of soap, and two of lamp-black.

Lithographic ink.

The composition for Lithographic ink is composed, according to M. Bartsch, of two parts or ounces of common soap, five parts or ounces of pure white wax, one-fourth part or one quarter of an ounce of grease, and one part or ounce of lamp-black; the latter ingredient to be greater or less, according to the fancy of the designer. Another recipe in frequent use has somewhat different proportions. Take of white bees' wax half a pound; of common yellow soap two ounces and a half; and of lamp-black one ounce. These substances, with the exception of the lamp-black, are then mixed and made to burn over the fire in an iron vessel; that is, suffered to remain till ignition has taken place, and at least one-third of the wax and soap has been consumed. The lamp black is then added, and the whole well stirred. The mixture must be poured out slowly on on iron or stone plate, and left to cool. When wanted for use, a portion of it is to be mixed with water in the same manner as Indian ink, and made of sufficient consistency to run freely from the pen, but should always be somewhat thicker than common ink.

Instruments for Lithography.

Lithographic instruments.—These are a port-crayon, a swan quill, an etching needle, a scraper, (such as for mezzotinto, Note DD.) a steel pen, a slab and muller, a pallet knife, camel's hair pencils, and dabbers. The latter are made of silk or soft glove leather (white kid leather is preferable) stuffed with cotton. The dabber is fixed to a handle about sixteen inches long, and is used like a hammer, that each stroke may bring the smooth leather surface in contact with the stone.

The stone plate must be kept clean during the work.

Precautions in drawing.—The Lithographer, while his drawing is in progress, must above all things be careful that nothing either wet or greasy touches his work; grease of any kind will be sure to print, and moisture will prevent his chalk from working with precision and clearness. Dampness even from breathing should be prevented, for which purpose a kind of fan made of paper may be placed before the mouth and nostrils to turn the breath in a different direction; or the stone, as M. Engelmann advises, may be moderately heated before it is drawn upon. The stone likewise must be kept quite pure from dust, and cleansed throughout with a perfectly clean dry camel's hair brush, otherwise the pellicules of dust entering the cavities in the grain of the plate will intercept the touches of the crayon. Any substance also of the nature of gum or glue must manifestly have the same injurious effect. The fingers must never touch the work. It is useful for the Draughtsman to support his wrist upon a bridge or rest about four or five inches wide, made to rise, at its lower surface, about one-eighth of an inch clear of the stone; and a margin of at least an inch wide must be left round the work for the necessary space required to lift or move the stone. The brush of camel's hair must also be repeatedly applied to sweep away the smallest particles which must unavoidably escape from the hair of the Designer while leaning over his work. Neither India rubber, nor crumbs of bread, must be used for effacing any errors which may be made by the lead pencil in sketching his outline; clean white leather may be employed; but these errors, unless the grain of the stone is injured by them, and unless they have been repeated by the afterwork of the crayon, or lithographic ink, are quite harmless, and will not come out in the impression. The face of the stone, when not in use, should be lightly covered with clean paper.

Practice of Lithographic Drawing.

Three modes of working.

The methods of working on the stone have been sometimes classed under two heads, according to the material used, namely, either the *crayon* above described, or the lithographic *ink*. In the use of the latter material, however, a third division of the Art should be added, called *Dabbing*. These three methods may be either practised singly or conjointly, according to the effect intended.

1. Lithographic crayon.

Tracings and Transfers.

Method of working in chalk.

1. *Crayon drawing.*—The Lithographic chalk should be kept dry and excluded from the air. If the subject is to be previously traced on the stone, French tracing paper should be used, not such as has been prepared with oil orvarnish. The tracing, being completed carefully on the paper with a soft black-lead pencil, is next laid with the penciling downwards on the stone surface, and fastened at its edges with strong gum-water or a few wafers, to prevent slipping. A sheet of soft paper is then placed above, and rubbed with a smooth piece of ivory or ebony. In this manner the lines of the pencil are transferred to the grained surface. Or the transfer may be accomplished by placing, as in Chalcography, (Note AA.) between the tracing paper and the Plate, a piece of white paper rubbed all over with the lead, (the rubbed side being laid downwards next the stone,) and then by going over the traced lines with a blunted steel point or etching needle. Tracing is recommended in preference to sketching on the stone with the black-lead pencil, as too much care cannot be taken to preserve and protect the grain of the stone. This grain for chalk drawing should be coarse rather than fine; particularly for portraits, otherwise the stippling of flesh will have a heavy and hard effect. A surface moderately grained is the best for the Lithographic crayon. Should the stone not be free from veins, care must be taken that the more delicate parts of the drawing do not come where the lines or spots appear. For delicate touches, the crayon should have a long and slender point, and should be used in a swan quill, which, by its lightness and elasticity, assists the hand in the operation. For strong touches, a firmer and shorter point is necessary, and the chalk should be placed in a port-crayon, which enables the hand to give firmness and precision of touch in the darker masses of the work. As the Lithographic crayon is apt to soften by much friction, a steady and rather slow motion of the hand is requisite to prevent specks and unevennesses in the work. These specks will cause infinite trouble to a hasty Draughtsman, as they must afterwards be carefully picked away with the etching needle, and swept from the surface with the brush. A finely-pointed crayon passed repeatedly backwards and forwards with a uniform steady motion, but not with heavy pressure, produces very fine dark lines. Soft chalk produces the greater depth of colour, but for more delicate parts, such as flesh, &c. a firmer kind of crayon is required. Dark masses are not to be obtained by heavy pressure, but by repeated hatching and stippling. Strong touches sufficiently broad to admit of a bluntish or firm point are procured by driving the chalk firmly against the grain of the stone. Any required depth of tone may be produced in this way. Sharp catching lights may be scraped out with the mezzotinto scraper, or fine light lines may be scratched with the etching needle. These latter operations must be performed with the utmost care and precision, since the scraped parts of the surface become too rough to take the chalk a second time, or too uneven to print with certainty. Some Lithographers soften their tints into each other by means of a mezzotinto cradle or grounding tool, (Note DD.) but this practice is unnecessary if the drawing be carefully executed; and the work will print much better without it.

The Artist will not fail to observe that the colour of the stone being darker than common drawing paper, his drawing will have a more finished appearance on the stone than when printed. He must therefore calculate accordingly, and not consider the colour of the stone as giving him any assistance by way of a middle tint, but must lay a proportionate tint over the lighter parts of his work.

2. Method of working in lithographic ink with a pen or brush.

2. *Ink drawing.*—The surface of the stone for ink drawings should have a delicate polish, which has been produced by finely powdered pumice-stone used after the fine sand. The process of tracing is similar to that for crayons above given, but is usually made with common red chalk. The ink is then made ready by rubbing the stick (like a cake of Indian ink) in a little warm or cold water; rain water, or distilled water, is the best. The ink for the pen should be less diluted than for the camel's hair pencil. The pens should have nibs of different breadths, according to the sort of lines to be drawn; and the hair pencils should be of the same kind, and in the same variety, as those used by Painters in miniature. Ink drawing requires more study and practice than crayon drawing. In laying on the colour with the brush, care must be taken that the greasy or soapy particles are spread uniformly, since on this, and not on the evenness of colour merely, depends the success of the future impression. A wash of the mere colour may have its proper tone, and look admirably well on the stone, and yet be utterly useless for printing: or the wash may be quite colourless; yet if a sufficiency of the greasy material be evenly imbibed, the impression will come out perfect. M. Engelmann recommends the practice of stippling, hatching, or dotting, whenever the pen or hair pencil are used. A union of pen-work with that of the hair pencil produces very agreeable effects; touches sometimes of the crayon may be added. Ink lines may also be put into a chalk drawing. The work of the hair pencil is less difficult than that of the pen; producing touches of greater delicacy and softness, and fewer blots. The progress, however, with the pencil is slower, the touches are sometimes not sufficiently charged with ink, and there is, on the whole, less freedom of execution. Architectural designs, or such as require great nicety, are sometimes outlined in ink, and finished in the crayon manner. The architectural Draughtsman will find his drawing pen of occasional use, but must be careful frequently to clear the point, and prevent it from being clogged with ink.

If ink drawing, however, requires more time and pains than the work of the crayon, the operator will be rewarded with a greater number of impressions. M. Engelmann remarks, that ink designs well executed on stone are almost inexhaustible; and that thirty thousand or forty thousand impressions from them have been taken without any perceivable difference between the first proofs and the last.

Mr. Nethercleft's method of transfer.

The following method, invented by Mr. Joseph Nethercleft, for transferring designs (drawn first on paper in lithographic ink) to the surface of the stone, was rewarded, in 1829, by a premium from the Society of Arts. The paper for the design receives first a wash of common size laid on with a camel's hair brush, and afterwards three coats of paste laid on in a similar manner carefully and evenly. The paste is made by boiling in separate vessels a quarter of a pound of tapioca, and the same quantity of arrow root, till each forms a paste. Let them then be united and mixed with a sufficiency of hot water to make a thin paste to be strained through a piece of muslin. Then add a quarter of a pound of flake white, previously well ground in water, and stir it in with the paste. The paper, when dry, should be either cold-pressed, or sent to the glazing-mill and flatted between two rollers. Two sheets, with their pasted sides contiguous, may be glazed together. The ink recommended by the inventor consists of equal quantities of yellow soap and shell lac boiled and burnt together, with sufficient lampblack to give it colour. In order to transfer the writing or drawing made with this ink with a steel or crow-quill pen on the prepared paper, let the stone be moderately warmed. Damp the back of the prepared paper till it lies perfectly flat, and be careful that no wet touches the prepared side containing the drawing or writing. Next lay the paper carefully on the warm stone with the wetted side upwards, and lay over it a sheet of soft paper, such as will absorb the wet. Pass the stone through the press three or four times with increased pressure, after which the paper will peel off, leaving the composition or paste, as well as the drawing, upon the stone. Wash off the paste, and lay a strong tint of gum arabic and water over the surface. When dry and cold the stone is ready for printing.

3. Use of the dabber.

3. *Dabbing.*—The stone for dabbing should be polished as for pen-work. After tracing the design upon it, according to the method above given for crayon drawing, the artist stops out his margin, and all the places where pure lights are to be left, with a mixture composed of gum-water, to which a little candied sugar powdered and a little gall have been added. This composition should be diluted sufficiently to work with tolerable freedom in the pencil, and the stoppings should be firm and decided. When the first stopping for the pure lights is completed and perfectly dry, he charges the dabbers with the Lithographic ink, dispersing it evenly over the surface. The first tint required is usually very light; the dabber therefore should be sparingly charged with colour, and tried by striking it on the surface of a spare piece of stone to ascertain what depth of colour it will give. If the tint be too light, it may be strengthened by repeated dabbing. Having obtained an even tint of this light kind over the surface of the plate, the Lithographer proceeds to stop out the light tints, taking care not to stop out more than is necessary. After this second stopping, he continues to ply his dabbers as before till he obtains the strength of the second tint; and in this manner alternately dabs and stops out until all the tints of his drawing, according to their due gradations, are completed. Minute markings and touches are obtained with difficulty by the dabbers alone: the chalk or pen therefore may be resorted to; and in cases where any stoppings have been omitted, the mezzotinto scraper or a sharp penknife may be used to lighten the tint in the faulty parts. Sometimes a mezzotinto grounding tool is useful to soften the tints after the process of dabbing. The reader will have probably observed that this process, called the "dabbing system," is admirably adapted for white ornaments on black or dark grounds.

Lithographic Printing.

Printing.

Report of M. Castellan on this subject.

We now come, lastly, to another series of operations which require perhaps more care than any of the foregoing. For printing from stone, a Press of a peculiar construction is required. A description of the Lithographic Press is attempted by M. Castellan in his Report to the Academy of Fine Arts at Paris, in 1816, who at the same time details the process of Printing as follows: *Le mécanisme de la presse diffère de toutes celles qu'emploient les imprimeurs en caractères, en taille douce, les dominotiers, et les imprimeurs d'étoffes. Cette presse consiste en une table creuse terminée à l'une de ses extrémités par des montans qui supportent un rouleau à moulinet; la table est recouverte d'un châssis garni d'un cuir fortement tendu. On place la pierre dans le creux de la table et on l'y assujetit au moyen de calles et de coins, puis on la mouille avec une éponge et de l'eau pure, jusqu'à ce qu'elle en soit bien saturée. Ensuite on charge la planche de noir au moyen d'un rouleau de bois ou manchon recouvert d'un cuir, et qui est lui-même impregné d'un noir d'impression extrêmement fin et compacte qu'il a pris en roulant sur un marbre chargé de cette matière; on promène ce rouleau plusieurs fois, et en tous sens, sur la pierre. La pierre étant donc chargée de noir, on étend dessus un papier d'impression, bien moins humide que celui qu'on emploie pour celle de la taille douce; alors le châssis retombe sur la table, et par dessus ce châssis une racle ou règle en bois qui, au moyen d'une bascule faisant agir deux leviers, exerce une pression de plus d'un millier de livres: enfin on met le moulinet en mouvement; la sangle attachée par son autre extrémité, à la partie mobile de la table dans laquelle la pierre est placée, s'enroule sur le rouleau, et fait glisser sous cette règle la superficie du châssis, qui sert d'intermédiaire entre elle et la pierre, et l'épreuve est imprimée. On relève alors la règle, on ouvre le châssis et on retire cette première épreuve, pour en faire sur-le-champ une seconde de la même manière, et sans déranger la pierre qu'on mouille à chaque fois. Pour conserver les planches lorsque le tirage est fait on les enduit d'une couche de gomme arabique, qui les met à l'abri de l'atteinte des matières grasses et du frottement qui pourraient gâter le dessin.* We despair of giving a better description of the Lithographic Press and its uses. To such of our readers as have never seen one, we recommend a visit to the establishments of some of our Lithographic Printers. That of M. Hullmandel is, as we before said, one of the earliest in London, and has met with deserved encouragement and success. The machinery of the Lithographic Press has undergone several improvements since the account above quoted as given by M. Castellan. The improved Press of Messrs. Taylor and Martineau, of London, is one of the simplest in construction, and most convenient for use. Two cast-iron uprights (see pl. i. fig. 11) form the sides of the Press, and are firmly attached to the base and table beneath. A carriage below containing the stone is supported by small rollers which considerably diminish the friction, and which move along a railway at the bottom of the table. The carriage is put in motion by means of a cylinder, to which a strong handle is attached; and the scraper (called in the above description by the French term racle) is depressed towards the stone by means of a spiral placed at the extremity of a handle for the purpose. A regulating screw is added for adjusting the Press to the various stones employed in the several branches of the art.

Improved press by Messrs. Taylor and Martineau.

Process of printing.

Before the Pressman submits the stone to the Press he must perform two very essential operations: first, he washes the stone with aquafortis well diluted in water. This solution prepares the stone to receive more readily the aqueous particles in the parts not intended for impression, and cleanses the surface likewise from dirt. A very weak solution, and such as will not excite effervescence, is required. When the whole surface has been wetted, fresh water is immediately used for rinsing it; and, when a sufficiency of water has been imbibed, a thin coat of gum arabic and water must be passed over it.

Secondly, the Pressman proceeds to the operation of charging the stone with printing ink, and applies his colour with a stuffed leather ball, pressed or dabbed perpendicularly on the surface, or with the common inking roller. For fac-simile of MSS. the roller is preferable. The printing ink must be applied carefully, and not too thick; otherwise, the lines will print broader than in the design, and be apt to spread over the stone by the pressure given in printing. The first impressions are generally feeble, and the operator must not expect a satisfactory result all at once, but must patiently repeat the process till a good impression is produced. The Plate, between each new application of the printing ink, must be thoroughly saturated with water. When signs appear of the Plate being clogged or overcharged with colour, (an accident which arises from a portion of the printing ink being left on the Plate after taking an impression,) the Plate must be cleaned by means of the following mixture: one part linseed oil, (or two parts olive oil,) two parts oil of turpentine, and three parts of water, shaken strongly together in a phial till they produce a foam. A small portion of the liquid well shaken is poured upon the Plate, and spread rapidly with a sponge over the entire surface. By means of this process, the black lines or shadings dissolve and become entirely obliterated: the oil of turpentine removes all greasy superfluities, while the linseed oil of the mixture supplies fresh nourishment to the drawing, and the water or third ingredient of the composition is drawn only to the parts where water has already been absorbed. The face of the stone, being now perfectly cleansed with a large sponge and fresh water, becomes as white as before the drawing was made, and the work, being no longer discernible on its surface, presents to the eye of a novice the appearance of being utterly spoiled. It must be left in this state for a short time, and is then to receive a thin coat of gum-water previous to the renewed application of the Printer's ink. All the original lines and touches of the drawing then reappear, and seem sharper and more distinct than ever. If, after an impression, the printing ink still shows a tendency to remain on the stone, a little diluted nitric acid may be carefully applied with a sponge to remove it. The operator must be careful not to use the same sponge indiscriminately for these several liquids, but must keep a separate sponge for each.

Paper.

Paper.—The paper for Lithographic impressions should be considerably thicker than for ordinary printing. If thin paper be used, intermediate layers will be necessary, that the scraper in printing may not come too near the drawing itself. Unsized thin paper is on this account unserviceable; since the printing ink, if very tenacious, will make the paper adhere to the Plate. All papers, in whose composition chalk or alum is present, are, says M. Bartsch, injurious to the stone.

Printing ink.

Printing ink.—M. Bartsch's recipe for printing ink is linseed oil well thickened by boiling, into which a sufficient quantity of lamp-black is afterwards well ground, till the whole mass is smooth and adhesive. Another recipe, which we copy from the *Encyclopæd. Edinensis*, recommends "one part grease or coarse soap; four parts white wax; one part gum lac; and one part lamp-black, bruised and very dry. In mixing these ingredients, the grease or soap is cut in small pieces, and put on a strong fire in an iron pot: this being well heated, the wax, also in small pieces, is introduced. After stirring it about, it is then set fire to with a match, and, while burning, the gum is added. When dissolved, extinguish the flame by covering up the pot; and, while the mixture is boiling, add

Notes on Engraving.

the lamp-black, still stirring it, till the whole is completely incorporated. It is then taken off the fire, and poured out on a plate of iron to cool. It becomes completely solid, and may be preserved in cakes. When wanted for use it will be cut into pieces, and dissolved in spirit of turpentine, or linseed oil, to a due consistency. It must not be ground very thin, as the lines will then be unequal and weak in their effect."

Temperature.—The temperature of the printing room is of much importance to the Lithographer. No season is so dangerous as hot weather, causing a rapid evaporation from the Plate, which cannot be too moist. On the other hand, in very cold weather impressions are not to be obtained till the Plate has been a little warmed, and the chamber well heated.

Note (MM.)

Among these several varieties in the practice of Lithography, some may require no further explanation than is to be collected from the foregoing Note; such are Nos. 1, 2, 3, 8, and 11. The method No. 4, for which several Plates are employed, and which we should call compound Lithography, (Art. 12.) differs only from the processes which we noticed under Wood Engraving, (Art. 28. and 30. Note (P.) or under Chalcography (Art. 46. 63. and 67. Notes (FF. and KK.) by the peculiarities already stated, which distinguish Lithographic Engraving and Lithographic Printing in general from Engravings on wood or metal. M. Bartsch remarks, that during the process of preparing the stone Plate for the Press by ablution in diluted aquafortis, the delicate tints of a crayon drawing sometimes become enfeebled and sometimes quite disappear; and recommends the use of a second stone Plate, on the surface of which the highest lights are left untouched, and the middle tints restored by some colour, either a yellow-brown or greenish-grey. This he terms the *toning* Plate. A moderately good stone (for the best kind is not necessary) is selected, and grained as for a chalk drawing; its whole surface to be covered over with an ink composed of four parts wax, one part soap, and two parts vermilion, not too thick, yet sufficiently strong to resist the action of the aquafortis. This ink, dissolved in rain water, is applied to the stone or toning Plate in a liquid state with a brush. When the reddened Plate is perfectly dry, a full impression from the original stone is taken, and this proof immediately applied for reimpression to the reddened stone. The red ground, being chiefly of wax, is easily scraped off in places where the drawing indicates that lights should be left. The same Plate is then washed with a solution of aquafortis, (about twenty parts water to one of the acid,) and, finally, coated with gum. It is then ready for giving impressions.

Compound Lithography.

Toning plate.

Retouching.

The discovery of a method for retouching, on the stone, any given portion of a Lithographic drawing, supersedes in some measure the process last mentioned. The honour of the invention is said to be divided between M. Hullmandel, of London, and M. Engelmann, of Paris, neither of whom, however, have published their *secret*, so that the claims of each competitor must remain *sub judice* until the disclosure of further evidence.

For imitation of mezzotinto, (No. 5.) the entire stone Plate (its margin of course excepted, which may be stopped out,) is to be covered with a coat of Lithographic ink (Note (LL.) dabbed uniformly over it, and care must be taken not to leave the substance too thick on the surface. A coat of thin varnish, or of gum arabic, is then passed over the plate, and after transferring the design, the Artist proceeds to remove the lights with his etching point or mezzotinto scraper. These instruments must be sufficiently sharp to clear away the ink, otherwise they will only serve to spread the oily or resinous vehicle, and cause extreme darks instead of lights. (See directions under *Dabbing* in the last Note.)

Lithography. Imitation of mezzotinto.

No. 6. differs little as to the vehicles used from the ordinary methods of this kind of printing. No. 7. requires only a good clear impression of the letter-press or copper-plate to be taken, and then, while yet wet, to be laid on the stone, which latter being passed through the press, receives an exact transfer of the printed matter. No. 9. is, we believe, seldom resorted to but where the scraper or the needle has failed of the effect intended, and consists in removing, by means of the graver, such portions of the surface as are required to be perfectly free from colour.

Of the method No. 10. the following account has been given. Let the stone Plate be covered with a solution of gum arabic coloured with lamp-black. When perfectly dry it is ready to receive the design, which is to be carefully proceeded with by means of etching needles of different thicknesses, according to the breadth of the several lines. The operator merely scratches off the coating of gum from the surface without making any incision into the stone. The analogy between this process and that of etching (Note BB.) is evident. The gum answers to the etching ground, and as the latter protects certain parts of the copper-plate from corrosion by the acid; so the former, in the present instance, preserves the stone from the action of oily or resinous matter. The Lithographic or resinous ink is now well rubbed over the stone, which is defended from it in every part but where the scratches have been made. The stone is then well sponged with water, and the ground of gum and lamp-black being thereby washed off the surface, the lines of the ink remain where the designer had rubbed them in. This process may be repeated till the operator is satisfied with his work. Instead of the resinous ink, the scratches may be filled up with copal varnish, which renders the design more durable, as the varnish when dry becomes very hard, and affords effectual resistance to alkalis, weak acids, oil of turpentine, or to alcohol; so that during the operation of printing the stone may be cleansed without injury by means of any one of those substances. The copal varnish, however, is only available for the rubbing process just stated; it is not sufficiently fluid to be manageable with a pen. M. Englemann remarks of this process, (*Manuel du Dessinateur Lithographe*, p. 69.) *Ce mode était dans son exécution presque aussi long, presque aussi difficile que la gravure à l'eau forte; on y a renoncé, et il n'est employé maintenant que par les personnes qui n'ont que des connaissances incomplettes dans le travail de la plume. Le seul cas où l'on peut recourir avec avantage à ce genre de gravure, c'est lorsqu'il s'agit de tracer des parties extrêmement fines, telles que les ciels et les lointains, que la plume ne rendrait certainement pas avec autant de délicatesse: en définitif, cette espèce de gravure offre des singuliers rapprochemens avec celle à la pointe sèche sur cuivre.*

Method for very fine work made [illegible] ing.

Reference to Plates iii. and iv. of Monograms used by some of the principal Engravers. Observe: the names numbered 1—18 are [illegible] of *French* Engravers: 19—56 of *German:* 57—93 of *Flemish* and *Dutch:* and 94—126 of *Italian.*

	No.		No.		No.
Agostino Venetiano	95	Boldini (Nicolo)	107	Daret (Pierre)	12
Aldegrever (Henry)	34	Bolswert (Scheltius a)	81	David (Jerome)	11
Altdorfer (Albert)	24	Bolswert (Adam a)	82	Davin, Daris, or Daret (Leon)	98
Amman (Jost, Justus, or Jodocus)	47	Bonavera (Domenico Maria)	126	Dellabella (Stefano)	122
Andreani (Andrea)	112	Bonasone (Giulio)	101	Durer (Albert)	25
Antonio (Marc) see *Raimondi*	99	Bos or Bosche (Jerome)	57	Duvet or Danet (Jean)	2
Assen (Walter van)	59	Brebiette (Pierre)	10	Fantuzzi (Antonio)	109
Audenaerde (Robert van)	89	Brie (Theodore de)	39	Fialetti (Odoardo)	115
Barbiere (Domenico del)	102	Broeck (Crispin Vanden)	63	Galle (Philip)	70
Barriere (Dominique)	15	Brosamer (Hans)	35	Garner (Antoine)	13
Baur (John William)	53	Burghmair (Hans or Johan)	31	Garnier (Noel)	3
Beccafumi (Domenico)	96	Callot (Jaques or Giacomo)	123	Gaultier (Leonard)	5
Beham (Hans Sebald)	30	Cantagallina (Remigio)	121	Ghein *the elder* (James de)	76
Beham (Bartholomew)	32	Caracci (Annibale)	113	Ghisi (Giovanni Batista)	104
Berghem (Nicholas)	83	Caraglio (Giovanni Giacomo)	110	Ghisi (Georgio)	105
Bernard (Solomon)	7	Castiglione (Benedetto)	124	Ghisi (Adamo)	106
Binck (James)	36	Chaveau (François)	15	Glockenton (Alert)	23
Bleck or Bleeck (Peter van)	91	Cock (Jerome)	64	Goltzius (Henry)	58
Bloemaert (Abraham)	78	Cort (Cornelius)	71	Guido, v. Reni.	
Boivin (René)	8	Cranach (Lucas)	28	Holbein (Hans) *doubtful*	26